UNIVERSITY OF ALBERTA

VARIATION IN MORTALITY RELATIONSHIPS

FOR MAJOR ALBERTA TREE SPECIES

BY

ATTA PANYIN ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

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And to keep me from being too elated by the abundance of revelations, a thorn was given me in the flesh, a messenger of Satan, to harass me from being too elated. Three times I besought the Lord about this, that it should leave me; but he said to me "My grace is sufficient for you, for my power is made perfect in weakness". I will all the more gladly boast of my weaknesses, that the power of Christ may rest upon me. For the sake of Christ, then, I am content with weaknesses, insults, hardships, persecutions, and calamities; for when I am weak then I am strong.

II Corinthians, 12 :7-10

Of so much happiness I never dreamed when I was an ugly duckling. You see it does not matter being born in a duckyard if you are from a swan's egg.

Hans Andersen in The Ugly Duckling.

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **VARIATION IN MORTALITY RELATIONSHIPS FOR MAJOR ALBERTA TREE SPECIES** SUBMITTED BY **ATTA PANYIN** in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE.**

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DATE: 21st January, 1992

Dedicated

to my mother (Aba Akosua Esuon) and to all mothers whose love for their children, like my mother's, knows no bounds.

to the Booth family of Canada, the Ampienyi family of Assorku-Essaman, Ghana and all those humanitarians God uses to reach out to his children.

to all those who live on the fringes of life.

to all my friends.

ABSTRACT

Average survival proportions for six major Alberta tree species growing in Volume Sample Regions (VSR) 3, 4, 5 and 6 were compared by way of mixed versus pure stands and of VSRs.

The methodology included the use of the logistic regression to estimate coefficients for the survival model, estimation of average sample survival proportions and significance tests for differences between survival proportions. One set of tests was carried out for the four VSRs on the basis of pure stands versus mixed stands for the same species. Another set of tests was carried out for the same species growing in different VSRs.

The Within VSR Comparisons showed that, one half of the differences between sample proportions were statistically significant at 95 percent probability level. Between VSR Comparisons showed sixty percent of the differences between sample proportions were statistically significant and forty percent statistically insignificant.

Survival probability models were fitted for combinations of species and VSRs. Independent variables for the survival model were median of dbh class and the stand basal area per hectare.

ACKNOWLEDGEMENT

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Sincere appreciation and gratitude are due members of the author's examining committee for the direction, encouragement and constructive crticisms provided all through the course of this study. Dr. S. J. Titus in particular must be singled out for commendation not only for his guidance from start to finish of this study, but also for the personal interest and extraordinary understanding he demonstrated for the author's cause.

Shongming Huang, a Ph.D candidate with whom the author was blessed as an office mate deserves special commendation for the invaluable assistance he rendered in the area of computer programming and companionship.

Finally, thanks be to God for making it all happen.

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1. INTRODUCTION

Stand level management has been the principal approach to the management of forests for a long time. This is due to the fact that a stand, while allowing for a close range study of individual trees in question, allows also for effective generalizations to be made about forests with respect to the principal stand characteristics such as cut, growth, mortality, and ingrowth (recruitment). Of particular importance is mortality because any forest yield prediction cannot be trusted without a reliable estimate of mortality.

1.1 Mortality

Mortality is the percentage of trees measured at the beginning of the period under review found dead at the end of that period. Mortality, whether in single trees or in stands, can be classified as regular or irregular (Lee 1971).

Regular mortality relates to overtopping and other competition-induced deaths and also deaths due to old age. Irregular mortality relates to incidents that cause trees to die in large numbers and usually over a short period of time. Such incidents include outbreak of diseases, insect infestation, fires, landslides, violent winds, etc. It is for this reason that irregular mortality is also referred to as catastrophic mortality.

1.2 Rationale for the study

Over the years, many models have been developed that describe and predict forest stand characteristics. Even though the literature is replete with models of various kinds, not much work is done in the area of mortality. The bulk of studies done in mortality like Newnham (1964), Lin (1974), Lee (1967) etc. for regular mortality and Monserud and Crookston (1982) for irregular mortality have been done outside the province of Alberta.

Since the scope of effective applicability of any model is limited in the main to the same environmental conditions and the region from where the data used to develop the model or a set of models are obtained (Hamilton and Edwards 1976), there is a need to develop mortality models specifically suited for Alberta conditions. In recent times attempts have been made to meet this need in Alberta. Morton and Titus (1984) developed preliminary survival models based on permanent sample plot data provided by the Alberta Forest Service (AFS). Since that study, the AFS data have been updated and edited.

This study uses the updated AFS data to update mortality models for six major Alberta species: white spruce *Picea glauca* (Moench) Voss., lodgepole pine *Pinus contorta* var. *latifolia* Engelm., aspen *Populus tremuloides* Michx., white birch *Betula papyrifera* Marsh., black spruce *Picea mariana* (Mill.) B.S.P., and balsam fir *Abies balsamea* (L.) Mill.

1.3 Study objectives

The objectives underlining this study are as follows:

1) To estimate coefficients of mortality relationships

using the logistic model for the six species in each of four Volume Sample Regions (VSRs) in Alberta.

2) To evaluate regional variation in survival or mortality for four VSRs in the province of Alberta.

3) To evaluate mortality variations between species growing in pure stands and those growing in mixed stands.

4) To document the procedures for summarizing the PSP data and estimating coefficients.

The progression towards these objectives begins with a discussion on the importance of forest mortality in forest management. That is followed by a review of some of the various approaches to mortality modeling. Such a review enhances the selection of a model type that best describes Alberta's major tree species. The methodology is next discussed in terms of the data, their source, and their processing. This is followed by the introduction of the logistic model used in this study to estimate the coefficients that allow for the prediction of mortality probabilities in major Alberta species. Results are then presented and with them, differences within regions and between regions are tested. The study concludes with a discussion of the findings and recommendations regarding the use of the models.

2. APPROACHES TO MODELING TREE MORTALITY

In a natural forest the annual gross growth is balanced by the annual mortality (Meyer 1953). Forest management is, to a large extent, an attempt with the aim of achieving some balance like the one that exists in natural forest. This is done by balancing growth and yield which balancing is not possible without mortality estimates which incidentally are difficult to obtain (Spurr 1952). The tools with which foresters estimate growth and yield are a wide range of models which necessitate the introduction of mortality estimates. Mortality models, therefore, are an indispensible part of stand dynamics models with which forests are managed.

2.1 Yield Tables

Yield Tables can be used to calculate stand dynamics. Like many stand dynamics models, net yield tables (the type most commonly used) rely on the introduction of mortality estimates from a different source before they can be used to make predictions (McArdle 1930).

Many models are available to foresters for modeling stand dynamics which have mortality estimates as a key component. An example is Bennet et al. (1959)

$$\ln(V) = a + \frac{b}{A} + cS + d\ln(N) + \frac{e}{S}$$

where

a, b, c, d and e are coefficients.

A = future age of stand

S = site index

N = number of trees estimated to survive at the end of the projection period.

This whole stand model can be solved for future yield (V) only if N can be estimated. The stand model above then relies on mortality models to provide N before V can be estimated. Models that provide such future values as N required in models like Bennet et al. (1959) are known as mortality functions. An example is Clutter and Jones (1980) that predicts future number of trees N_2 from current number of trees N_1, current age A_1 and future age A_2 as follows:

$$N_2 = [N_1^{-.8708} + .0000146\,(A_2^{1.3745} - A_1^{1.3745})]^{(-.8708)}.$$

To obtain the future yield, N_2 calculated from the mortality function above is substituted into the model developed by Bennet et al. (1959). It is obvious from the above that an accurate estimation of survivals at a certain future time is essential in the study of stand dynamics Avery and Burkhart (1983). Smalley and Bailey (1974) and Pienaar and Shiver (1981) are other examples of mortality functions.

The modeling of gross growth of initial stand volume also can be modeled only if a good mortality estimates are available. The gross growth of initial stand volume (G_g) is given by

$$G_g = V_2 + M + C - I - V_1$$

where

V_1 = stand volume at the beginning of growth period

V_2 = stand volume at the end of growth period

M = mortality volume

C = cut volume

I = ingrowth volume

(Husch et al. 1982).

In this model mortality has to be introduced from a mortality model before G_g can be calculated.

2.2. Diameter Class/Distribution

The importance of good mortality estimates that can be used in whole stand models and elsewhere has led to the generation of mortality models within the diameter class and the diameter distribution system. An example is the Weibull distribution probability.

The diameter distribution allows for the use of the Weibull distribution model. The model can be used to determine survivorship among populations--biological or non biological. Another use to which the Weibull distribution is put is the prediction of the distribution or the structure of a population, as in Little (1982) which used Weibull to predict the distribution of diameter classes of mixed stands of western hemlock and Douglas fir.

An important component of the Weibull distribution model is the notion of survivorship curves: type 1, type 2 and type 3 (Lemon 1975 and Pinder et al. 1978). These curves are a graphical expression of the probability that a member of the population will survive to a certain age "t". The probability is expressed as a function of age.

A type 1 survivorship curve results when the age-specific mortality rate (ie the probability that death occurs in the time interval t_i to t_{i+1} given that the object in question lives up t_i) increases with increasing "t" (Pinder et al. 1978). A type 2 survivorship curve results when the age-specific mortality rate is constant and type 3 is when the age-specific mortality rate decreases with "t".

The Weibull has been popular because it lends itself to many applications in modeling. It has three main components. 1) a continuous independent variable "t", usually time, 2) a scale parameter "b", and 3) a shape parameter which is "c". Given t the cumulative frequency F(t) under the Weibull distribution function is given by

$$F(t)=1-EXP(-(\frac{t}{b})^{c})$$

where t, b, and c > 0

The features of the Weibull distribution described above allow managers of forest resources to apply the Weibull in the modeling of mortality in a stand. With those characteristics as tools, forest managers can study survival rates, mortality rates and patterns of stand dynamics.

Somers et al. (1980) is an example of a forestry application of Weibull distribution. In that study, survival in even-aged stands of loblolly pine from ages 3 to 14 years was modeled using a modified Weibull function as follows:

$$N_i = N_a EXP(-(\frac{X_i}{b})^c)$$

where

N_i = number of surviving trees per ha at age i

N_a = initial number of trees per ha at age 3

X_i = age

"b" and "c" are Weibull parameters (Somers et al. 1980).

2.3 Individual Tree Models

In recent times mortality models have been based on stand characteristics as well as on individual tree characteristics. These models are either distance dependent or distance independent.

2.3.1 Individual Tree Distance Dependent Models

Individual tree distance dependent models are based on tree characteristics such as height, dbh, crown size, taper, etc and stand characteristics such as basal area.

Distance dependent models are unique since in addition to those characteristics, each individual tree is mapped to determine its distance to others, its bearing, and sizes of all adjacent trees that are engaged in competition with it for resources (Davis and Johnson 1987, pg. 133). Because they provide detailed information about the stand, individual tree distance dependent models can be used to study various stand features like competition, mortality due to insect defoliation, and average bole form change.

Mortality can be estimated using distance dependant models deterministically or stochastically. The deterministic assignment of a tree staying alive or the probabilty of survival in this case, then, becomes dependent on the influence neighboring trees exert on subject trees. The result of considering the effect all neighboring trees have on a subject tree is that individual distance dependent models produce a more detailed information about the stand than do individual tree distance independent models.

Individual distance dependent mortality models are particularily useful for predicting mortality because of the high premium they place on competition. Mortality probabilities are determined as functions of the competition index values. They are able to predict the effect of cultural practices on yield with a very high degree of accuracy and have the ability to predict mortality more accurately (Munro 1973). The disadvantages associated with these models include expensive computer time and costly stem chart and their extreme complexity.

Bella (1970), Arney (1972, 1976), Daniels and Burkhart (1975) Hann (1978) and Michelle (1969) are examples of these models. Hegyi (974) is another example developed specifically to be applicable to jack pine since an earlier model, Arney (1972), developed for Douglas fir was found not completely suitable for jack pine because irregularities of jack pine's crown affected Arney model.

2.3.2 Individual Tree Distance Independent Models

Individual tree distance independent models use as predictor variables stand characteristics such as number of trees per Ha, average heights, dbh classes, site index and age. These models do not take into account the distances a tree shares with its neighbors. The major assumption underlying this approach is that "spatially all species and sizes of trees are uniformly distributed throughout the stand" (Davis and Johnson 1987, pg. 132).

Two types of individual tree distance independent models are generally recognized: deterministic and stochastic.

When distance independent models are used to predict mortality, it is important to determine which trees will be designated as dead and which will be live. This is the deterministic approach as was used in Newnham (1964). He called a tree dead if its growth was less than a certain percentage of its dbh. Lin (1970) considered a tree dead if it had been suppressed for six continuous years.

Stochastic means can also be followed to create single tree distance independent models as in Hamilton (1974) for predicting mortality of western white pine in northern Idaho and Monserud (1976). In this approach, a tree is assigned a probability value which indicates its chances of surviving for the next year. When a stochastic method is used to model mortality for a group of trees having identical tree characteristics, the survival probability value for the group indicates the propor . of the group that will survive for the next year. Here the specific trees that will survive are unknown since chances of survival are random.

Other examples of stochastic mortality functions in use include Michelle (1967), and Morton and Titus (1984), These models are based on the probability of survival defined to be dependant on tree characteristics. Dress (1970) used a stochastic method based on complex mathematics. On the other hand Reimer (1973), and Stage (1973) used the empirical method. Hamilton and Edwards (1976) is a well known example which predicts the survival probability of individual trees. Single tree distance independent models have the advantage of being applicable to a species over a wide range of sites and are good for thinning and spacing alternatives. It has been argued by some reseachers (Munro 1973) that because distance independent models do not consider inter-tree distances, they are not as accurate as their distance dependant counterparts.

2.4 Summary

Under approaches to modeling tree mortality, the impotance of mortality estimation in forest management has been mentioned. It has also been mentioned that because foresters need good mortality estimates which can be used in whole stand dynamics models, they have come out with different kinds of models that provide mortality estimates. These types of models include diameter distribution models like the Weibull, and individual tree models which are either distance dependent or distance independent.

The models developed in this study are of the individual tree distance independent type. The study used the logistic regression to estimate the annual individual tree survival probabilty for major Alberta tree species and follow Hamilton and Edwards (1976) with some modifications as described under section 3.

3. METHODOLOGY

3.1 Study Area

In 1960, the Alberta Forest Service (AFS) began establishing plots in Alberta that would provide the AFS with data needed for the study of Alberta's forests stands. These permanent sample plots (PSPs) provide inventory data from each of the Volume Sample Regions (VSR) on continuous basis. These VSRs are the major management units in Alberta and coincide approximately with Alberta's major climatic and vegetational zones (ecoregions). Depending upon the age of stands and forest type (coniferous or deciduous), measurements are made of tree and stand characteristics once in every five or ten years. For coniferous stands less than eighty years or more than 130 years, and deciduous stands less than sixty years or more than 100 years, measurements are taken every ten years. For coniferous stands between eighty and 130 years, and deciduous stands between sixty and 100 years, measurements are taken every five years (AFS PSP Field Procedures Manual, 1990).

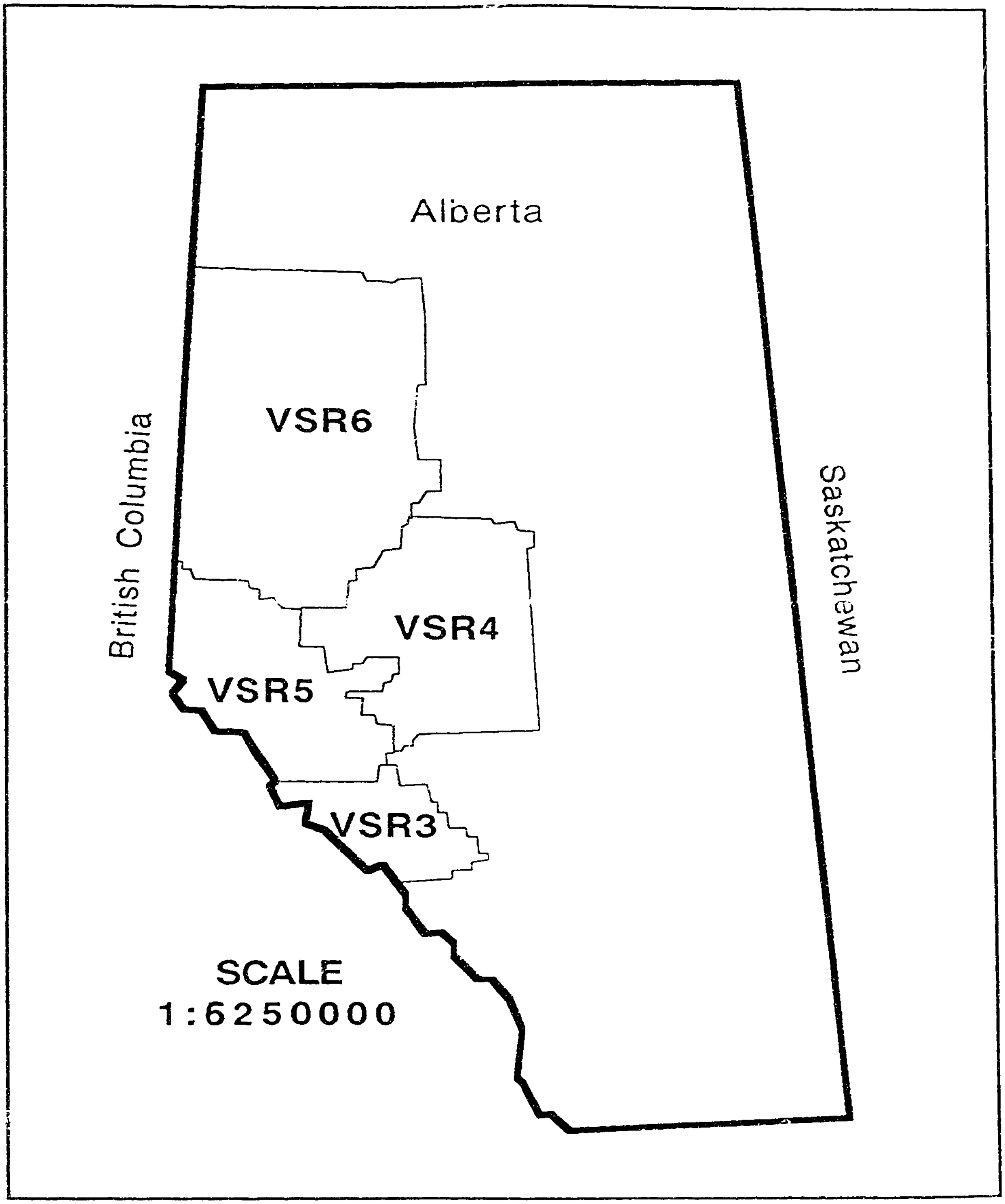
Four of the VSRs in Alberta formed the study area for this project: VSR3-VSR6 (Table 1 and fig. 1). These were selected in consultation with the AFS as representing broad topographical, vegetational and climatic zones. The selected VSRs coincide approximately with the following ecoregions of Alberta.

Table 1: Study area related to relevant ecoregions in Alberta

VSR	ECOREGION	AREA%	AREA km^2
3	Subalpine	3.5	23,133
4	Boreal mixedwood	43.2	285,611
5	Boreal foothills	9.6	63,362
6	Boreal mixedwood	43.2	285,611

source: Strong and Leggat (1981)

Figure 1. Study area in Alberta.



3.1.1 Subalpine

VSR3 is located within the subalpine ecoregion. The ecoregion itself stretches northward along the Rocky Mountains in both the British Columbia and USA (Ross and Hunter 1976) but the permanent sample plots that constitute VSR3 are found only in the pine subregion of the ecoregion. VSR3 rises between 1600 and 2134 metres above sea level (Anderson 1978, 1979; and Strong 1979). The VSR has a dominance of coniferous forests but on warm sites deciduous species such as aspen occur (Strong and Leggat 1981).

The pine subregion, one of the three subregions into which the subalpine ecoregion is divided by ecologists (Pfister et al. 1977) basically coincides with VSR3 and has lodgepole pine as the dominant species. Spruce is the codominant species in the part of the VSR that rises above and beside the pine subregion.

3.1.2 Boreal Mixedwood

VSR4 and VSR6 fall in the main in the boreal mixedwood ecoregion which comprises 43.2% of Alberta (Strong and Leggat 1981). Trees in the ecoregion are mainly deciduous. Balsam fir and white spruce are the potential climax species but the ecoregion is currently dominated by aspen and spruce. Lodgepole pine is rare except in the south of the ecoregion which coincides with the southern third of VSR4. Here lodgepole pine occurs in such sufficient numbers in stands as to be classified as pure stands.

3.1.3 Boreal Foothills

VSR5 is located roughly in the area classified as the boreal foothills ecoregion. VSR5 is a transitional zone and is therefore very diverse in species. Species found there include aspen, balsam poplar, lodgepole pine, white spruce. Strong and Leggat (1981) attribute the occurrence of lodgepole pine within the deciduous forest stands to the cooler, moister summer and relatively warmer winter climate of the boreal foothills ecoregion.

3.2 Data Description

The AFS PSP data data base for this study are comprehensive in that they can be used for a wide variety of forestry studies. For all trees with diameter at breast height (dbh) greater than 9.1cm, dbh, crown size, condition of the tree, etc. are recorded together with site observations such as slope, location, dominant vegetation as determined by the crown class, plot size, etc. Height is measured for a sample of trees.

Measurements of interest to this study were the dbh and basal area per hectare. These formed the basis for the two variables, median of the diameter class and basal area per hectare, used as covariates in the study. Since repeated measurements are carried out on every tree at the end of each measurement interval, it is possible to keep track of each tree at each measurement. This is of particular importance to this study since it is necessary to know the mortality as time progresses.

3.3 Data Preparation

Using the Statistical Analysis System (SAS), a program was written to summarize the AFS data pertaining to VSR3, VSR4, VSR5 and VSR6. These data were then processed separately for each VSR and for each of the species in the VSR. Appendix VI is a summary of stand information at first measurement.

The example described below for VSR4 shows how data were prepared and processed for use in the logistic regression to estimate coefficients for the prediction of the survival probability.

White spruce in the data file from VSR4 was first isolated and summarized by dbh. The summary was planned such that bad records could be discovered. An example of a bad record is when a particular tree has measurement records of its dbh at first and third measurements but no record at its second measurement. Another example of a bad record is an entry which has not been designated as dead yet has no dbh measurement.

The Alberta Forest Service was consulted about these bad data entries which the AFS assigned a condition code of 77. A review of the AFS PSP field entries from VSR4 did not yield any values for the missing entries coded 77. It was decided that a check be done to assess the extent to which condition code 77 appears in the data file being used for this study. Six groups (1-6) corresponding to six plots were selected for a quick check. For white spruce, five trees out of 232 in six plots had condition code of 77. For aspen, four trees out of 245 in the six plots were affected. It was decided that such entries should be removed from the data set to be used for analysis.

3.3.1 Individual Tree Characteristics

The AFS data file for VSR4 has 96 PSP groups with each group consisting of four plots. The first plot of each group was selected for study. Trees in each plot had been measured since establishment at least three times with the exception of the relatively new plots established in 1984. These repeated measurements allow for the scrutiny of the progress of individual trees over time.

To obtain an overall picture of how trees are doing from establishment to the fourth remeasurement, a SAS program (appendix III) was written to summarize the entire AFS file such that PSP group number, diameter, status of a tree at the beginning of each measurement period and at the end of the period appeared as a single record. Individual tree numbers were also retained. That way, individual trees could be traced and crosschecked with the original AFS PSP data should a verification become necessary. Trees which had only one measurement were deleted since two or more measurements are needed in order to detect mortality patterns. A sample output listing is shown below as Table 2.

Table 2: Sample listing showing mortalities over measurement period

The SAS System

OBS	GRNUMB	TRNUMB	DBH1	DCLASS1	COND1	LOGPD1	DBH2	DCLASS2	COND2
1	1	14	19.6	8	22	5.1	20.3	9	0
2	1	92	15.7	7	0	5.1	16.0	7	0
3	1	101	14.7	6	0	5.1	14.5	6	0
4	16	2621	10.7	5	19	7.9	12.7	6	0
5	16	2637	11.2	5	28	7.9	13.5	6	0
6	16	2638	10.9	5	28	7.9	13.2	6	0
7	16	2642	10.7	5	0	7.9	12.7	6	0
8	16	2652	15.7	7	0	7.9	17.0	7	0
9	16	2672	8.9	4	28	7.9	10.4	5	0
10	16	2673	10.2	5	28	7.9	11.7	5	0
11	16	2674	9.9	4	15	7.9	11.9	5	0
12	16	2714	7.1	3	0	7.9	8.9	4	0
13	16	2729	8.1	4	0	7.9	9.9	4	0
14	16	2755	15.5	7	0	7.9	17.8	8	0
15	18	3366	3.8	2	23	7.9	4.8	2	0
16	18	3369	16.5	7	28	7.9	17.8	8	0
17	18	3370	11.9	5	28	7.9	12.7	6	0
18	18	3371	2.5	2	13	7.9	4.1	2	13
19	18	3372	1.3	1	0	7.9	2.3	1	0
20	18	3374	2.8	2	0	7.9	4.3	2	0
21	18	3375	17.3	7	0	7.9	19.3	8	0
22	18	3379	1.5	1	0	7.9	3.0	2	0
23	18	3385	3.8	2	0	7.9	4.8	2	0
24	18	3390	2.8	2	0	7.9	3.6	2	0
25	18	3393	24.1	10	13	7.9	24.9	10	13
26	18	3405	14.7	6	0	7.9	15.7	7	0
27	18	3406	22.1	9	23	7.9	22.9	10	0
28	18	3408	15.0	7	28	7.9	15.2	7	0
29	18	3409	21.3	9	28	7.9	21.8	9	0
30	18	3416	16.0	7	0	7.9	16.8	7	0
31	18	3417	17.5	8	0	7.9	17.8	8	0
32	18	3420	1.5	1	0	7.9	3.0	2	0
33	18	3421	1.5	1	0	7.9	2.8	2	0
34	18	3432	1.5	1	0	7.9	3.0	2	0
35	18	3433	17.5	8	0	7.9	18.0	8	0
36	18	3434	19.3	8	0	7.9	19.6	8	0

GRNUMB: the PSP group number

TRNUMB: tree number

DBH1: diameter measured at establishment (first measurement)

DBH2: diameter measured at second measurement

DCLASS1: diameter class of tree at establishment

DCLASS2: diameter class of tree at second measurement

COND1: condition of tree at establishment

COND2: condition of tree at second measurement

LOGPD1: the time difference between a tree's two measurements.

Tree growth fluctuates with the seasons, with high growth rate in summer and little or no growth in winter. For example white spruce under 40 cm in Alberta does not grow in height between late June and August (Hellum 1967). Since the AFS plots are measured at different times of the year, dbh growth calculations based on the calendar months do not portray the biological process that occurs in the trees. Some studies in Alberta recognized this fact and made some adjustment. In this study adjustments were made to the lengths of the growth period after the fashion of Morgan and Titus (1984) to reflect the fluctuations in tree growth with the seasons. Thus the following adjustments were made to the lengths of the growth period in this study.

Months 1-4 assigned a value of 0.0.

Month 5 assigned a value of 0.2.

Month 6 assigned a value of 0.5.

Month 7 assigned a value of 0.9;

Months 8-12 assigned a value of 1.0.

With these values the lengths of the growing period in this study were adjusted and incorporated into the data set summarized as above.

Trees in the data set were assigned a dbh class and then sorted by dbh class. The median of each diameter class was assigned to all trees in that class. Then the number of trees alive in each dbh class at each measurement period was calculated using the "PROC MEANS" approach as outlined in the

Statistical Analysis System (SAS) Procedures Guide (1988) and SAS User's Guide (1985). The data set containing the number of trees surviving at each measurement was merged with the data set mentioned above containing group numbers so reference could be made to it on a group by group basis. The resulting data set ended the summarization of tree characteristics needed for this study. An identical treatment was given to each of the six species in each of the four volume sample regions.

3.3.2 Plot Characteristics

As stated in the literature review, individual trees distance independent models rely on both tree level and stand characteristics. A good model is parsimonious. The literature is replete with excellent models that are based on one or two variables. This study used two variables. The stand level variable chosen was total basal area per ha of all trees (regardless of species) in a plot. This approximated competition level for each stand. To obtain this information, a SAS program was written to extract it from a summary data and plot characteristics document (Huang and Titus 1990) previously prepared for the Alberta Forest Service and for the purpose of this and other related studies.

The extracted basal area per ha referred to in this study as Bahpl was then merged with the individual tree characteristics data set prepared as above by group number. The next step is to distinguish between mixed and pure stands since the probabilities of survival in pure and mixed stands are compared for appropriate species.

3.3.3 Distinguishing Between Pure and Mixed Stands

The distinction between mixed stands and pure stands was based on a simple formula

$$PCTCOMP_i = \frac{BAH_i}{BAHPL}$$

where

BAH_i refers to total basal area of species i,

BAHPL refers to the total stand basal area (all species),

$PCTCOMP_i$ refers to the proportion of the total stand basal area occupied by species i; i = 1,....6.

These proportions coded 1 to 9 were assigned to all permanent sample plots by species coded 1 to 6 (see below) and by VSR. Upon consultation with the Alberta Forest Service, it was decided that any PSP having a PCTCOMP of any particular species of at least 80% constitutes a pure stand of that species. If a PSP had a PCTCOMP of less than 80% it constituted a mixed stand. Thus all permanent sample plots in the four volume sample regions which formed the study area for this study were distinguished between pure and mixed by species. The SAS procedure SAS FREQ was then used to obtain the tables 3-6.

In the tables reading down, species group (SPGRUP) 1 through to 6 refer to white spruce, lodgepole pine, aspen, white birch, black spruce and balsam fir respectively. Reading across, if

percentage composition (PCTCOMP) = 1 then that species' basal area (BAH) occupies between 0 and 10% of the total basal area (BAHPL). Similarly if

PCTCOMP = 2 then BAH is between 10 and 20%

PCTCOMP = 3 then BAH is between 20 and 30%

PCTCOMP = 4 then BAH is between 30 and 40%

PCTCOMP = 5 then BAH is between 40 and 50%

PCTCOMP = 6 then BAH is between 50 and 60%

PCTCOMP = 7 then BAH is between 60 and 70%

PCTCOMP = 8 then BAH is between 70 and 80%

PCTCOMP = 9 then BAH is greater or equal to 80%.

In each cell reading down, the first number is the frequency of plots with same PCTCOMP. The second number gives the percentage of the first number to all the plots in the VSR in question. The third number gives the percentage of the first nunber to the number of plots constituting the species in question and the fourth number gives the percentage of the first number to total number of plots with the same PCTCOMP in the VSR in question.

The SAS System

TABLE 3: TABLE OF SPGRUP BY PCTCOMP FOR VSR3

SPGRUP PCTCOMP

SPGRUP (Frequency / Percent / Row Pct / Col Pct)	1	2	3	4	5	6	7	8	9	Total
1	4	4	1	2	2	6	0	1	5	25
	3.77	3.77	0.94	1.89	1.89	5.66	0.00	0.94	4.72	23.58
	16.00	16.00	4.00	8.00	8.00	24.00	0.00	4.00	20.00	
	9.52	66.67	20.00	33.33	28.57	100.00	0.00	33.33	17.24	
2	3	1	2	3	3	0	1	2	24	39
	2.83	0.94	1.89	2.83	2.83	0.00	0.94	1.89	22.64	36.79
	7.69	2.56	5.13	7.69	7.69	0.00	2.56	5.13	61.54	
	7.14	16.67	40.00	50.00	42.86	0.00	50.00	66.67	82.76	
3	9	0	0	0	0	0	0	0	0	9
	8.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.49
	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	21.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
4	5	0	0	0	0	0	0	0	0	5
	4.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.72
	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	11.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
5	14	0	1	1	1	0	0	0	0	17
	13.21	0.00	0.94	0.94	0.94	0.00	0.00	0.00	0.00	16.04
	82.35	0.00	5.88	5.88	5.88	0.00	0.00	0.00	0.00	
	33.33	0.00	20.00	16.67	14.29	0.00	0.00	0.00	0.00	
6	7	1	1	0	1	0	1	0	0	11
	6.60	0.94	0.94	0.00	0.94	0.00	0.94	0.00	0.00	10.38
	63.64	9.09	9.09	0.00	9.09	0.00	9.09	0.00	0.00	
	16.67	16.67	20.00	0.00	14.29	0.00	50.00	0.00	0.00	
Total	42	6	5	6	7	6	2	3	29	106
	39.62	5.66	4.72	5.66	6.60	5.66	1.89	2.83	27.36	100.00

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TABLE 4: TABLE OF SPGRUP BY PCTCOMP FOR VSR4

SPGRUP (Frequency / Percent / Row Pct / Col Pct)	PCTCOMP 1	2	3	4	5	6	7	8	9	Total
1	39 9.03 42.86 24.22	13 3.01 14.29 23.64	8 1.85 8.79 25.81	7 1.62 7.69 22.58	6 1.39 6.59 40.00	3 0.69 3.30 16.67	5 1.16 5.49 22.73	4 0.93 4.40 18.18	6 1.39 6.59 7.79	91 21.06
2	11 2.55 13.41 6.83	4 0.93 4.88 7.27	5 1.16 6.10 16.13	4 0.93 4.88 12.90	1 0.23 1.22 6.67	6 1.39 7.32 33.33	6 1.39 7.32 27.27	8 1.85 9.76 36.36	37 8.56 45.12 48.05	82 18.98
3	24 5.56 33.80 14.91	9 2.08 12.68 16.36	7 1.62 9.86 22.58	8 1.85 11.27 25.81	3 0.69 4.23 20.00	3 0.69 4.23 16.67	5 1.16 7.04 22.73	4 0.93 5.63 18.18	8 1.85 11.27 10.39	71 16.44
4	39 9.03 65.00 24.22	14 3.24 23.33 25.45	2 0.46 3.33 6.45	1 0.23 1.67 3.23	0 0.00 0.00 0.00	3 0.69 5.00 16.67	1 0.23 1.67 4.55	0 0.00 0.00 0.00	0 0.00 0.00 0.00	60 13.89
5	25 5.79 39.06 15.53	10 2.31 15.63 18.18	6 1.39 9.38 19.35	7 1.62 10.94 22.58	3 0.69 4.69 20.00	0 0.00 0.00 0.00	2 0.46 3.13 9.09	3 0.69 4.69 13.64	8 1.85 12.50 10.39	64 14.81
6	23 5.32 35.94 14.29	5 1.16 7.81 9.09	3 0.69 4.69 9.68	4 0.93 6.25 12.90	2 0.46 3.13 13.33	3 0.69 4.69 16.67	3 0.69 4.69 13.64	3 0.69 4.69 13.64	18 4.17 28.13 23.38	64 14.81
Total	161 37.27	55 12.73	31 7.18	31 7.18	15 3.47	18 4.17	22 5.09	22 5.09	77 17.82	432 100.00

The SAS System

TABLE 5: TABLE OF SPGRUP BY PCTCOMP FOR VSR5

SPGRUP Frequency Percent Row Pct Col Pct	PCTCOMP 1	2	3	4	5	6	7	8	9	Total
1	9 8.91 56.25 25.71	0 0.00 0.00 0.00	2 1.98 12.50 22.22	0 0.00 0.00 0.00	1 0.99 6.25 16.67	1 0.99 6.25 50.00	0 0.00 0.00 0.00	2 1.98 12.50 40.00	1 0.99 6.25 4.76	16 15.84
2	2 1.98 5.88 5.71	2 1.98 5.88 22.22	1 0.99 2.94 11.11	1 0.99 2.94 16.67	2 1.98 5.88 33.33	0 0.00 0.00 0.00	4 3.96 11.76 50.00	3 2.97 8.82 60.00	19 18.81 55.88 90.48	34 33.66
3	8 7.92 50.00 22.86	1 0.99 6.25 11.11	1 0.99 6.25 11.11	2 1.98 12.50 33.33	1 0.99 6.25 16.67	1 0.99 6.25 50.00	2 1.98 12.50 25.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	16 15.84
4	6 5.94 46.15 17.14	2 1.98 15.38 22.22	1 0.99 7.69 11.11	1 0.99 7.69 16.67	2 1.98 15.38 33.33	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 0.99 7.69 4.76	13 12.87
5	8 7.92 47.06 22.86	3 2.97 17.65 33.33	3 2.97 17.65 33.33	1 0.99 5.88 16.67	0 0.00 0.00 0.00	0 0.00 0.00 0.00	2 1.98 11.76 25.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	17 16.83
6	2 1.98 40.00 5.71	1 0.99 20.00 11.11	1 0.99 20.00 11.11	1 0.99 20.00 16.67	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	5 4.95
Total	35 34.65	9 8.91	9 8.91	6 5.94	6 5.94	2 1.98	8 7.92	5 4.95	21 20.79	101 100.00

The SAS System

TABLE 6: TABLE OF SPGRUP BY PCTCOMP FOR VSR6

SPGRUP / PCTCOMP Frequency Percent Row Pct Col Pct	1	2	3	4	5	6	7	8	9	Total
1	7 2.45 9.09 7.69	5 1.75 6.49 9.43	3 1.05 3.90 10.34	5 1.75 6.49 21.74	11 3.85 14.29 50.00	13 4.55 16.88 72.22	13 4.55 16.88 61.90	9 3.15 11.69 75.00	11 3.85 14.29 64.71	77 26.92
2	9 3.15 24.32 9.89	9 3.15 24.32 16.98	7 2.45 18.92 24.14	3 1.05 8.11 13.04	1 0.35 2.70 4.55	1 0.35 2.70 5.56	4 1.40 10.81 19.05	2 0.70 5.41 16.67	1 0.35 2.70 5.88	37 12.94
3	9 3.15 12.86 9.89	17 5.94 24.29 32.08	14 4.90 20.00 48.28	12 4.20 17.14 52.17	8 2.80 11.43 36.36	3 1.05 4.29 16.67	3 1.05 4.29 14.29	1 0.35 1.43 8.33	3 1.05 4.29 17.65	70 24.48
4	44 15.38 65.67 48.35	13 4.55 19.40 24.53	4 1.40 5.97 13.79	2 0.70 2.99 8.70	1 0.35 1.49 4.55	0 0.00 0.00 0.00	1 0.35 1.49 4.76	0 0.00 0.00 0.00	2 0.70 2.99 11.76	67 23.43
5	9 3.15 75.00 9.89	1 0.35 8.33 1.89	0 0.00 0.00 0.00	1 0.35 8.33 4.35	0 0.00 0.00 0.00	1 0.35 8.33 5.56	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	12 4.20
6	13 4.55 56.52 14.29	8 2.80 34.78 15.09	1 0.35 4.35 3.45	0 0.00 0.00 0.00	1 0.35 4.35 4.55	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	23 8.04
Total	91 31.82	53 18.53	29 10.14	23 8.04	22 7.69	18 6.29	21 7.34	12 4.20	17 5.94	286 100.00

The procedure outlined above and the tables clearly provided two groups of data to be analysed and compared in this study. But there was a third group of data that constitutes a part of the study. Considering appendix II and Tables 3-6, it is obvious that after the plots had been classified into pure and mixed, some groups did not have enough plots to warrant a reasonably separate analysis for the group for that species in that VSR. In such cases, trees in that species group in that particular VSR are regressed as one group. In this study, where no specific mention was made of a species belonging to either a pure stand or a mixed stand, then the species concerned constituted the third group and was run as such.

Analysis of species in the third group is important in order to satisfy the need to know the mortality rates or the probability of survival not only in pure and mixed stands but also in all stands that constitute the VSR.

3.3.4 Measurement Interval

Since 1960 the Permanent Sample Plots have been remeasured in 1965, 1968 and 1984. Sometimes, some measurements are carried out between the main measurement times. This presented this study with the difficult problem of choosing particular years as the beginning and end of the study period. Choosing say, 1960 to 1965 for example, will leave out many trees that were measured for the first time in say 1968. Since the crux of the study is to trace the progress of individual trees after their first measurements and since as noted above first measurements do not fall on one particular year, it was decided to use the first interval. That is, the period between any first measurement and its first remeasurement. Trees which have had no more than one measurement were removed from further study because mortality cannot be determined from one measurement. For each of the six species, there were many different first measurement periods. In order to obtain a singl figure for use in the regression, the average measurement period (L1) of all trees of same species was taken for each of the four volume sample regions.

3.3.5 Species with Insufficient Data for Further analysis

In VSR3, white birch was present in only five permanent sample plots. Further analysis revealed that none of the white birch in the five PSPs had been remeasured since establishment. Since white birch had no measurement interval to work with, it was eliminated from further analysis. Aspen in VSR3 occurred in nine plots. Eight of these plots had 28 aspen trees with at least two measurements but suffered no mortality during the measurement interval. Aspen was therefore removed from the species regressed for coefficients.

In VSR4, all six species were retained for the regression runs (see Table 7).

White birch in VSR5 occurred in thirteen plots. In six of these plots white birch occupied less or equal to one percent of the total basal area of the plots in which they occurred. In two plots the percentage was two. That left insufficient data to work with. White birch was therefore removed from the regression runs.

In VSR6, black spruce occurred in twelve plots all of which had been measured more than once. But as Table 6 shows, black spruce typically occupied a very small percentage of the total stand basal area. Besides, during the measurement interval only six mortalities were recorded. Black spruce was therefore removed from further analysis. Table 7 is a list of species retained. Bold uppercase letters (X) indicate species run for mixed stands and for pure stands. All others mixed and pure were grouped separately.

Table 7: Species retained for use in regression runs.

	VOLUME SAMPLE REGION			
SPECIES	3	4	5	6
Aspen (Aw)		x	x	x
Lodgepole pine (Pl)	**X**	**X**	**X**	x
White spruce (Sw)	x	x	x	**X**
Black spruce (Sb)	x	x	x	
Balsam fir (Fb)	x	x	x	x
White birch (Bw)		x		x

3.4 Fitting Mortality Models

Since this study is about biological samples, it has an important purpose of fitting a model that is not only parsimonious and provides a reasonable fit but also one that most reasonably approximates the relationship between the response variable and the covariates. This study is concerned with the probability that a single tree survives. This means that the response variable takes two values 0 and 1, corresponding to "dead" and "alive" respectively. This is known as binary response (Hosmer and Lemeshow 1985) or dichotomous response (Monserud 1976 and Grizzle, Starmer and Koch 1969).

3.4.1 Problems of Linear Regression with Binary Data

In this study, the nonlinear regression model was used because a nonlinear model overcomes the two main problems that [illegible]t that make the linear regression model

$$Y_i = a + bX_i + e_i \ , \quad i=1,.....n$$

where

Y_i is the i^{th} value of the response variable

X_i is the i^{th} value of the explanatory variable

e_i is the i^{th} error term

and

a and b are unknown regression parameters unsuitable for the analysis of data for a dichotomous response variable.

The first problem is the violation of the constant error variance assumption (Wrigley 1976).

With dichotomous response variables, the error term

$$e_i = Y_i - (a + bX_i)$$

can only have one of two possible values:

$e_i=1-(a+bX_i)$ when $Y_i=1$, and $e_i=-(a+bX_i)$ when $Y_i=0$.

These possible values occur with probabilities of P_i and $1-P_i$ respectively because of the binary nature of Y_i, where $p_i = p(Y_i = 1)$.

Based of the assumption: $E(e_i) = 0$, it can be shown that the constant error varriance is

$$E(e_i)^2=P_i(1-(a+bX_i)^2 + (1-P_i)(-(a+bX_i))^2.$$

This, violates the constant error variance assumption since the value of $E(e_i)^2$ and hence of $\sigma^2_i=Var(e_i)=E(e^2_i-(E(e_i))^2$ depends upon the values of the independent variable. With the violation of the constant error assumption, if ordinary least square method is used to estimate the unknown parameters a and b, will not be the best. Of course, there exist techniques such as weighted least squares when we have heterogeneity of variances, but in any case (see the next paragraph) a normal theory analysis would be incorrect. Ramanathan (1989, pg. 474) and Maddala (1988, pg. 167, 269) add that if the normality assumption is violated, estimated coefficients a and b can be inconsistent and inefficient if, say, the error distribution has a flatter than normal distribution. This adversely affects the testing of hypotheses to be carried out later since the tests critically depend upon normality.

For a normal theory analysis to be appropriate, the response variable should, at the very least, be approximately continuous over some interval; obviously this fails for the binary response variable in this study.

Though many nonlinear models are available for the analysis of binary data, this study employs the use of the logistic regression model for a number of reasons.

3.4.2 The Logistic Model

If $x_1, \ldots\ldots\ldots x_n$ are a collection of independent variables and y is a binary response variable such as yes and no or alive and dead, with probabilities of success (survival) of p and 1-p respectively, then the logistic regression model is written as

$$logit(p) = \ln\left(\frac{p}{1-p}\right) = \alpha + \beta_1 x_1 + \ldots + \beta_n x_n$$

Solving for p gives the form in which the logistic model is commonly seen and used:

$$\hat{P}_i = \frac{1}{1 + e^{\alpha + \beta_i x_i + \ldots\ldots + \beta_n x_n}}$$

The second form shows that the value of $\hat{P}$ is always between 0 and 1 irrespective of the values the x_i assumes. It is this property of the logistic model that makes it appropriate for this study. In this study the logistic model is modified after the fashion of Monserud (1976) in order to model a yearly probability of survival as follows:

$$\hat{P}_i = \frac{1}{[1 + e^{(-(A + Bx_1 + Cx_2))}]^{Li}}$$

where

$\hat{P}_i$ = a fraction between 0 and 1. It is the estimated proportion of trees in a dbh class surviving the length of growth period.

x_1 = MD1 = median = median of dbhclass (cm).

x_2 = BAHPL = basal area per ha all species in a plot in M^2.

L1 = adjusted length of growth period

A, B, C are parameters to be estimated.

The logistic model has been modified by many researchers to suit specific data sets and study objectives. Monserud (1976) and Hamilton and Edwards (1976) and Hamilton (1986) modified the logistic model to take care of the unequal measurement intervals by raising the model to a power equal to the length of the measurement interval. In this study, the Monserud's modified model is adopted with a modification. Hamilton and Edwards (1976) used the same model and weighted the predicted probability by the magnitude of the measurement interval. This translated the predicted probability of survival to a yearly rate. While this may be good, it leaves some uncertainty as to whether in the words of Morton and Titus (1976), "consistent measures of the status over the interval are being minimized" in the least squares estimation method Hamilton and Edwards (1976) used. This study weights the predicted probability with the magnitude of the number of trees per diameter class used in the regression. This means that if a diameter class experiences many mortalities during the measurement interval, the probability of survival being predicted will be smaller and vice versa. This intuitively makes more sense since the greater the mortalities the smaller the probability of survival. This study departs from Hamilton and Edwards (1976) and Morton and Titus (1984) in that it uses the MLE as the estimation method as per SAS PROC NLIN.

The logistic model was favored in this study for the following reasons:

1) The logistic model is mathematically flexible and easy to use.
2) A literature review, for example, of Morton and Titus (1984), Hamilton and Edwards (1976), Hamilton (1974, 1980, 1986), Monserud (1976) and Edelstein-Keshet (1988) provides evidence that the logistic model yields a biologically meaningful interpretation.
3) The logistic model ensures that the predicted values always lie between 0 and 1 (Ramanathan 1989, Ratkowsky 1983 and Jennrich and Ralston 1979).

3.4.2.1 The Logistic Regression by SAS PROC NLIN

The procedure favored for this study was the PROC NLIN outlined in the SAS System for Regression (1986). PROC NLIN was favored because it is more practical and more flexible. It is more practical as compared to the PROC CATMOD because it allows for the output of statistical information necessary for testing the model. It is flexible because SAS PROC NLIN allows for the the calculation of annual survival probability after the fashion of Morton and Titus (1986) and Monserud (1976) taking into account the average measurement interval referred to as L1.

To apply the PROC NLIN, trees surviving at the first remeasurement (N2) were designated Y=1 (1 being live). Trees that died during the interval were designated Y=0 (0 being dead). To obtain the number of deads, the difference between the number of trees at establishment (N1) and at the end of interval (N2) was taken. The number corresponding to each dbhclass was used as a weight in the regression to fit the model.

The use of SAS PROC NLIN requires that initial values of the parameters be estimated and fed to the procedure. In a logistic regression, any starting values will do if MLE is the method of estimation because of the concave nature of the likelihood function (Maddala 1988, pg. 273 and Pratt 1981). Initial values reasonably close to the true parameters being estimated will shorten the convergence time with few iterations and thus save computer time. If the initial values fed to the procedure are too far removed from the correct values very many iterations will occur resulting in waste of expensive computer time or the regression may not converge at all. Also if multiple maxima or many local maxima exist in addition to an absolute maximum, poor starting values may result in convergence to an unwanted stationary point (Draper and Smith 1966, Draper 1987). With these in mind, every effort was made to obtain the best possible starting values.

The PROC CATMOD (SAS Procedure Manual) was used to regress median dbh (MD1) and BAHPL on Y without taking the interval length into account. After the coefficients given by the Catmod procedure had been compared with Morton and Titus (1986) and found to be reasonably close, they were used as the starting values in the SAS PROC NLIN.

3.4.2.2 Maximum Likelihood Estimation

Many methods are available for use in the estimation of unknown parameters in regressions, for example least squares estimation and maximum likelihood estimation (MLE). In linear regression cases the least squares method which lends itself to a straight forward mathematical calculation and the maximum likelihood method give the same estimators (Maddala 1988). But in nonlinear regression a different estimation method must be used. The maximum likelihood estimation is the estimation type preferred and used by SAS in the PROC NLIN procedure. Indeed the choice of SAS PROC NLIN was influenced by the fact that the estimation type that SAS uses is the MLE. The principle of maximum estimation is based on the intuitive notion that " an event occurred because it was most likely to" (Ramanathan 1989). The principle of maximum likelihood estimation follows thus:

If X is a random variable and the density of X at a point x is $f(x,\theta)$, and if x_i, $i = 1,\ldots\ldots n$, are a sample of observations on X, then the likelihood $L(x_i,\ldots.x_n,\theta)$ of the sample is defined as

$$L(x,\theta) = \Pi_{i=1}^{n} f(x_i,\theta)$$

and loosely represents the probability of the sample $x_i, \ldots, x_n$ actually observed (Jennrich and Ralston 1979).

The maximum likelihood estimate of θ is the value of θ that maximizes L. Based on the above principle, it is clear that the MLE deals efficiently with probability estimation and thus is an appropriate estimation method for this study. It is the estimation method that SAS employs in the PROC NLIN procedure. In addition to the appropriateness of the MLE to this study, MLE has a number of advantages: Under regularity conditions, the maximum likelihood estimation (MLE) estimates are consistent and asymptotically normal, and are often efficient.

Altogether, 24 regression runs were carried out with the species retained in accordance with the criteria for retention (section 3.3.5). Table 7 summarises the species used in the four volume sample region in the regression runs.

3.5 Types of Comparisons Made

In order to investigate whether or not significant differences exist in mortality rates within and among the four volume sample regions which form the study area in this study, two sets of comparisons were carried out: Within VSR comparisons and Between VSR comparisons.

3.5.1 Within VSR Comparisons: Pure stands Versus Mixed Stands

In the same VSR, mortality estimates for individual species are compared between mixed stands and pure stands. Owing to limitations of the data, the following comparisons were made:

B) VSR4 lodgepole pine mixed versus VSR4 lodgepole pine pure

C) VSR5 lodgepole pine mixed versus VSR4 lodgepole pine pure

3.5.2 Between VSRs Comparisons: Regional Differences

Between VSRs comparisons were made for same species but growing in different VSRs. This provided evidence as to whether or not a particular species growing in two VSRs exhibited a statistically significant difference in mortality rates in the two regions. Owing to limitations of the data, the following comparisons were made:

A) VSR3 white spruce versus VSR4 white spruce

B) VSR4 aspen versus VSR6 aspen

C) VSR4 white birch versus VSR6 white birch

D) VSR4 balsam fir versus VSR6 balsam fir

E) VSR5 black spruce versus VSR4 black spruce.

3.6 Testing for Regional Differences

The method employed in accomplishing the comparisons outlined above is the comparison technique for binomial populations outlined in Huntsberger and Billingsley (1987) and in Evelyn Caulcott (1973). The method compares the probability that a tree that survived belongs to one of two binomial populations. The method was used for both within VSR comparisons and between VSRs comparisons. This comparison technique has three underlying assumptions:

1) Independent random samples.

2) Normal populations.

3) Equal variances of the populations compared.

The second assumption is not a particularly stringent one, and if the samples are sufficiently large, even large departures from normality will not affect the comparisons much because of the central limit theorem: "if several random variables are identically distributed, their mean will be asymptotically normal even if the random variables were originally not normal" (Huntsberger and Billingsley 1988, pg. 323). The samples used in this study are sufficiently large and therefore make the second assumption a valid one.

Assumption number three is met by the fact that populations of species growing in pure stands can be expected to have the same variance especially so since they come from the same volume sample region. This is reinforced by the fact that the f being used in the comparison phase is by virtue of it being the arithmetic mean of all the individual tree proportions, the centre of gravity of all the single tree probabilities that make up the probability mass function modeled using the logistic regression. This gives tree populations of the same species a more or less equal variance (Harnett, 1970).

3.6.1 Normal Approximation to the Binomial

The primary object is to find out whether given any two VSRs the probability (proportion) of survival for a random tree belonging to a given species is greater in one of the VSRs than the other. If the survival proportions in the two VSRs are P_1 and P_2 respectively, then the aims are to find out if

1) P_1 is not equal to P_2., then
2) to estimate the difference between P_1 and P_2.

Since the population probabilities (P_1 and P_2) are unknown, the sample survival proportions obtained from the regression runs and averaged for each VSR are used to make inferences about P_1 and P_2. If f_1 and f_2 are the estimated survival proportions for the samples drawn from the two VSRs the unbiased estimate for P_1 and P_2 are f_1 and f_2 respectively. Similarly the difference between P_1 and P_2 is estimated unbiasedly by the difference between f_1 and f_2.

If n_1 and n_2 are the two sample sizes the estimated variances of f_1 and f_2 are respectively given by

$$S_{f_1}^2 = \frac{f_1(1-f_1)}{n_1}$$

and

$$S_{f_2}^2 = \frac{f_2(1-f_2)}{n_2}$$

If n_1 and n_2 are large and independent, then d, the difference between f_1 and f_2 has approximately a normal distribution and the variance of d is the sum of the variances, and is estimated by

$$s^2_{f_1-f_2}=\frac{f_1(1-f_1)}{n_1}+\frac{f_2(1-f_2)}{n_2}$$

The alternatives to test are

$$H_o: P_1 = P_2,$$
$$H_a: P_1 \neq P_2.$$

Now f_1 is an unbiased estimate of P_1 and f_2 is an unbiased estimate of P_2. Since $P_1=P_2$ under H_o, it can be shown that the best estimate of their common variance is the weighted average of f_1 and f_2 given by

$$f_p = \frac{n_1 f_1 + n_2 f_2}{n_1+n_2}.$$

Since the variance is assumed to be equal for the same VSR or for same species in two VSRs from which the two populations are taken, separate estimates of variance could be calculated for each population. But the best estimate is obtained by pooling the two samples (Huntsberger and Billingsley 1987). Thus the best unbiased estimate of the variance of difference d is given by

$$s^2_d=f_p(1-f_p)\left(\frac{1}{n_1}+\frac{1}{n_2}\right)$$

The standard deviation of $d = f_1-f_2$ is estimated by The test statistic used to reject or accept H_o and to

$$s_d=\sqrt{s_d^2}=\sqrt{f_p(1-f_p)\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$$

draw inferences ab ut the population of species in the four volume sample regions is the Z-statistic (Z_{cal}) calculated using the formula

$$Z_{cal} = \frac{d}{s_d} = \frac{f_1-f_2}{\sqrt{f_p(1-f_p)\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}}$$

where

f_1 is the estimated survival proportion for sample1

f_2 is the estimated survival proportion for sample2

f_p is the pooled survival proportion that best estimates the unknown common proportion P under H_o: $P_1 = P_2$

n_1 and n_2 are sample sizes for sample1 and sample2 respectively.

The form of the test depends upon the alternative test, H_a. Since H_a is two-sided, a two-tailed test is used in all the paired comparisons under intra VSR comparisons and under inter VSR comparisons. The level of significance employed in the test is 5%. In two-tailed tests such as this, the decision rule is reject H_o if

$Z_{cal} >= 1.96$ or if $Z_{cal} < -1.96$.

3.6.2 Average Proportions

The estimated average survival proportion f_θ for a particular species was obtained by two steps.

1) Using the estimated coefficients in the logistic model a

survival proportion ($\hat{P}_i$) was estimated for each tree according to its diameter (MD1) and the total basal area per ha (BAHPL).

2) These survival proportions ($\hat{P}_i$) are then averaged over the total number of observations (N1) used in the SAS PROC NLIN. The result from step 2 is the estimated average survival proportion (f_θ) for that species in that VSR or in that mixed group or in that pure group shown below. In the formulae,

$$f_\theta = \frac{\sum_{i=1}^{n} \hat{P}_i}{n}$$

f_θ is the estimated average proportion for a species in a volume sample region or for a species growing in mixed or pure stands in a volume sample regi...

n = N1 = the number of observations.

$\hat{P}_i$ is the estimated survival proportion f... which constitute a dbh class for the spec... ...der consideration. $\hat{P}_i$ is later assigned to trees i = 1,......,N1 according to the dbh class they belong to and

θ refers to mixed or pure or a VSR

This provided a single estimated average proportion for a species in a VSR or for a mixed stand or pure stand in a VSR. These single proportions (f_θ) were those used in the comparison phase.

3.6.3 Sample Test for Lodgepole pine in VSR4: Mixed Species Versus Pure Species

Since all the tests carried out in this study followed the same principles and formulae discussed above, only one such test was done as an example using lodgepole pine trees growing in mixed stands in volume sample region 4 versus lodgepole pine growing in pure stands in the same volume sample region. The major question addressed in the sample comparison below was: Do lodgepole pine trees growing in mixed stands and in pure stands in VSR4 have the same survival rates?

The question is answered with reference to VSR4 in table 8 which lists species, the number of trees measured at the first measurement (N1), ..e number of trees measured at the second measurement (N2), the number of mortalities (DEAD) and the estimated average probability calculated f_θ and the average measurement period L1. The information used to answer this illustrative question is drawn from Table 8.

The estimated average probability that a lodgepole pine growing in a mixed stand survives in VSR4 is

$$f_\theta = f_{Plmixed} = .9522$$

and that of lodgepole pine in a pure stand in VSR4 is

$$f_\theta = f_{Plpure} = .9370.$$

Then $d = f_{Plmixed} - f_{Plpure} = .9522 - .9370 = .0152$

$$N1_{Plmixed} = 1704$$

$$N1_{Plpure} = 3764$$

f_{Pooled} is calculated as follows:

$$f_{pooled} = \frac{1704(.9522) + 3764(.9370)}{1704 + 3764}$$

$f_{pooled} = .94174$

$s^2_d = s^2_{Plmixed - Plpure} = .000046777$

$s_d = .0068393$

The Z-value is calculated thus

$$Z_{cal} = \frac{f_{Plmixed} - f_{Plpure}}{s_d}$$

$Z_{cal} = 2.2224$

The test hypotheses are

H_o: $p_{Plmixed} = p_{Plpure}$

H_a: $p_{Plmixed} \neq p_{Plpure}$

and the decision rule for this two-tailed test is

Reject H_o if $Z_{cal} >= 1.96$ or $Z_{cal} < -1.96$

There is evidence that survival rates are different for lodgepole pine growing in mixed and pure stands in VSR4. The calculated Z-value being positive indicates a higher survival probability in VSR4 for lodgepole pine growing in mixed stands as opposed to pure stands.

4. RESULTS

4.1 Summary Information used in the Regression procedure

Table 8 below shows the actual number of trees of each of the six species used in the SAS PROC NLIN.

Table 8: Summary of Information Used in the PROC NLIN

VSR	TYPE	SP	N1	N2	DEAD	L1
3	A	Sw	2082	1979	103	9.92
3	M	Pl	528	499	29	9.25
3	P	Pl	3143	2991	152	0.83
4	A	Sw	3165	2871	294	10.51
4	A	Aw	2748	2337	411	10.31
4	A	Bw	517	438	79	10.14
4	A	Sb	2878	2691	187	10.69
4	A	Fb	1044	948	96	9.95
4	M	Pl	1704	1605	99	12.19
4	P	Pl	3764	3552	212	10.36
5	A	Sb	898	852	46	8.48
5	M	Pl	767	724	43	9.80
5	P	Pl	1804	1645	159	8.10
6	A	Pl	975	865	110	13.13
6	A	Aw	2115	1768	347	12.16
6	A	Bw	217	188	29	12.30
6	A	Fb	1081	920	161	12.13
6	M	Sw	3122	2879	243	12.61
6	P	Sw	651	593	58	12.23

In the table above, N1 refers to the number of trees measured at the beginning of the measurement period and N2 the number measured at the end.

Dead is the number of trees that died during the measurement period.

L1 is the average length of the measurement period for a sample.

Under Type, A refers to All trees of a particular species run as one group for the VSR in which they occur.

M refers to trees of a particular species growing in mixed stands in the VSR in which they occur.

P refers trees of a particular species growing in pure stands in the VSR in which they occur.

Only the species retained for further analysis are shown in the table above.

4.2. Results from Regression Runs

Tables 9 and 10 are a summary of coefficients estimated by the 24 regression runs using the logistic model in the SAS PROC NLIN procedure. Each run converged after an average of eighteen iterations. The tables also show the asymptotic 95% confidence interval associated with each of the parameter estimates. The 95% confidence interval was the criterion for deciding which coefficient estimates were acceptable and which were unacceptable.

Table 9: Rejected coefficients.

			ESTIMATES			95% CONFIDENCE INTERVAL		
VSR	SP	TYPE	A	B	C	A	B	C
3	Pl	M	2.1176	.1253	.0270	(-1.567, 5.802)	(-.046, .297)	(-.049, .104)
3	Fb	A	4.6769	.3467	-.0212	(-2.471, 11.82)	(-.228, .923)	(-.231,.188)
3	Sb	A	3.7337	.1610	.0060	(-1.355, 8.942)	(-.204, .526)	(-.099, .111)
5	Sw	A	19.7200	.8004	-.5542	(-3.642, 43.08)	(-.147, 1.748)	(-1.27, .162)
5	Fb	A	8.2967	-.0406	-.1055	(-4.646, 21.24)	(-.231, .149)	(-.42, .205)
6	Sw	M	3.0651	.1982	-.0184	(-1.574, 7.706)	(-.045, .441)	(-.107, .070)
6	Pl	A	-.1251	.1847	.0417	(-3.331, 3.081)	(.111, .259)	(-.044, .1217)

Table 10:

Acceptable coefficients for predicting surviival probability for an individual tree

VSR	SP	TYPE	ESTIMATES A	B	C	95% CONFIDENCE INTERVAL A	B	C
3	Sw	A	5.6831	.5774	-.0769	(3.691, 7.674)	(.344, .811)	(-.121, -.033)
3	Pl	P	5.3556	.5575	.0969	(2.285, 8.426)	(.191, .924)	(-.173, -.018)
4	Sw	A	5.6613	.0690	-.0397	(5.056, 6.266)	(.034, .104)	(-.051, -.029)
4	Aw	A	2.7864	.1213	-.0244	(2.262, 3.311)	(.093, .150)	(-.038, -.011)
4	Bw	A	3.8797	.0619	-.0179	(2.543, 5.217)	(-.001, .125)	(-.047, .011)
4	Sb	A	5.6615	-.0814	.0103	(3.695, 7.828)	(-.135, -.027)	(-.032, .052)
4	Fb	A	5.2498	.0314	-.0252	(2.994, 7.506)	(-.050, .112)	(-.057, .007)
4	Pl	M	5.0760	.0122	.0049	(3.490, 6.662)	(-.058, .082)	(-.041 .052)
4	Pl	P	5.2377	.6194	-.1660	(4.063, 6.412)	(.406, .833)	(-.226 -.106)
5	Aw	A	10.3410	.2332	-.2926	(1.144, 19.54)	(.029, .437)	(-.62, .033)
5	Sb	A	4.2250	.3589	-.0331	(.602, 7.849)	(.035, .683)	(-.116, .050)
5	Pl	M	3.8619	.3029	-.0626	(.680, 7.043)	(.092, .513)	(-.135, .010)
5	Pl	P	5.1974	.1908	-.0953	(1.484, 8.911)	(.089, .293)	(-.204, .013)
6	Aw	A	3.4177	.0787	-.0203	(2.551, 4.284)	(.052, .106)	(-.046, .006)
6	Bw	A	5.9619	-.0232	-.0315	(3.340, 8.583)	(-.086, .040)	(-.093, .030)
6	Fb	A	2.4788	-.0474	.0566	(1.026, 3.932)	(-.093 -.002)	(.011, .102)
6	Sw	P	5.4843	.0766	-.0358	(3.205, 7.763)	(.022, .131)	(-.091. .019)

4.2.1 Acceptable and Unacceptable Estimates

A scrutiny of tables 8, 9 and 10, reveals three clear patterns running through all the coefficients estimated. These patterns were detected by observing the coefficient estimates rejected and accepted using the 95% confidence interval associated with each coefficient. The patterns are as follows:

1) Acceptable coefficients were generally obtained where the number of trees belonging to a species used in the regression procedure was at least 500 with mortalities of at least 100.
2) Acceptable coefficients were obtained if the proportional mortality was high even though the number of mortalities was lower than 100.
3) Where the number of trees used in the regression procedure was greater than 500 but the proportion of mortalities was low, coefficient estimates were generally unacceptable.

Based on the fact that coefficient estimates with no zero value within its associated 95% confidence interval are generally acceptable, coefficients estimated for balsam fir and black spruce were removed from the species used in the comparison phase for VSR3. Estimates for lodgepole pine growing in mixed stands in VSR3 were considered unacceptable for use in a model. In VSR4, all the estimates were considered acceptable. In VSR5, white spruce, and balsam fir were considered unacceptable and therefore removed from the comparisons phase. Estimates for all species but lodgepole pine and white spruce growing in mixed stands in VSR6 were also unacceptable. In Table 10 above, some coefficient with the possibility of assuming a zero value were retained because they were reasonably close to those obtained by similar studies eg, Morton (1990).

4.2.2 Fitted Equations

The actual fitted equations were obtained by substituting the accepted estimates of the coefficients A, B and C into the logistic model for the appropriate species and volume sample region. The $\hat{P}_i$ obtained by substituting the coefficients into the logistic model is an estimate of annual proportion or the probability that a tree growing in a mixed or pure stand or growing in a given VSR which survived for a year belongs to a dbh class the median dbh of which is MD1. Assuming that other factors remain constant, this translates into the prediction: the estimated probability that an appropriate individual tree belonging to a dbh class of median dbh MD1 growing in a stand with density BAHPL survive for a year is $\hat{P}_i$. Appropriate tree means the tree about which survival prediction is being made must belong to the species type and the VSR for which the model was fitted according to Table 10.

4.3 Comparisons

Within and Between VSR Comparisons were made as described in section 3.6.1 above.

4.3.1 Within VSR Comparisons

Table 11 gives a summary of the outcome of the comparisons for mixed and pure stands of the same species and in the same VSR. In Table 11 below, θ in f_θ has been replaced with m for mixed or p for pure for the same species in a VSR.

Table 11 MIXED AND PURE STANDS COMPARISONS BY VSR

VSR	SP	Z_{CAL}	ST.DEV.	f_m	f_p	$f_m - f_p$
4	Pl	2.2224*	.0068	.9522	.9370	.0152
5	Pl	2.5864*	.0121	.9357	.9044	.0313

* significant at 5% level

Table 11 shows that for lodgepole pine growing in VSR4 there was a statistically significant difference between the average survival probabilities of mixed and pure stands. The same result was obtained for lodgepole pine growing in VSR5. In both VSRs, survival probabilities were higher in mixed species stands as compared to pure species stands.

4.3.2 Between VSRs Comparisons

The Between VSRs comparisons (Table 12) involved more species than the Within VSR Comparisons. In the Table, θ in f_θ is replaced with 1 or 2 where 1 refers to the first VSR in "3,4" and 2 refers to the second VSR. In Table 12, "3,4" means that the estimated average probability for white spruce growing in VSR3 ($f_{1=VSR3}$) was compared with the estimated average probability of white spruce growing in VSR4 ($f_{2=VSR4}$).

Table 12 BETWEEN VSR COMPARISONS

VSR	SP	Z_{CAL}	ST. DEV.	f_1	f_2	$f_1 - f_2$
3,4	Sw	4.9550*	.0059	.9711	.9416	.0295
4,6	Aw	1.1845	.0097	.8756	.8641	.0115
4,6	Bw	-.1446	.0284	.8553	.8594	-.0041
4,6	Fb	13.6191*	.0130	.9898	.8120	.1778
4,5	Sb	-4.0507*	.0098	.9194	.9592	-.0398

*significant at 5% level

White spruce growing in VSR3 was compared with white spruce growing in VSR4. As Table 12 shows, the difference in their estimated survival probability was significant with white spruce in VSR3 more likely to survive. Aspen and white birch growing in VSR4 did not show any significant difference in survival probability when compared with their counterparts in VSR6 even though aspen in VSR4 had a slight edge in survival probability over that in VSR6 and white birch in VSR6 had a slight edge over white birch in VSR4.

Significant differences existed in survival probability for balsam fir growing in VSR4 and balsam fir growing in VSR6. The survival probability difference for black spruce in VSR4 and black spruce in VSR5 was also found to be significant. In both species survival was less in VSR4.

5. DISCUSSION

The logistic model was used to find coefficients which can be used as estimates of parameters about four important Volume Sample Regions in Alberta. There is the temptation for a researcher faced with a project such as this study to look for elegance and sophistication in the belief that the more variables a model has or the parameters to estimate the better the model, and indeed many forest scientists have gone that way. One only has to glance through summary papers like Prodan (1968) and Grosenbaugh (1965) to appreciate the immense complexity that exists in forest modeling. In spite of all genuine efforts to find the best model to describe forest dynamics, as Yang et al. (1978) put it, "a function that is flexible enough in form to accommodate all biological growth behavior and logical enough in theory to justify its applications in practice has been unavailable".

In this study, the logistic model was adopted for both its simplicity and its ability to model biological phenomena. Care was taken to limit the number of coefficients to be estimated (constant included) to three. Since the object of nonlinear regression is to find a parsimonious model that exhibits a close-to-linear behavior (Ratkowsky 1990), the more variables in a model the more likely it is for the model to deviate from a close-to-linear behavior, and the more unreliable its estimates are for a given study size.

Bearing in mind all the above, two variables, the medians of all the dbh classes and basal area of each plot expressed in M^2 per Ha were chosen as the explanatory variables in this study. Some studies performed in the area of forest tree mortality (Morton and Titus 1984) used individual tree dbh as one of the independent variables. Morton (1990) used the mid-point of the dbh classes he developed to estimate coefficients in the Mixedwood Growth Model "MGM" he developed for the Alberta Forest Service. In this study, the medians of the diameter classes were used because the median is considered a more robust estimator relatively unaffected by outliers (Barnett 1983). The other variable used in this study (basal area) is the most appropriate as a variable when trees are grouped into diameter classes (Thomas and Paresol 1989). Being a function of radius and radial growth, basal area, when used as a variable in a model, takes care of many of the factors that affect forest tree mortality. The main function of the basal area in the model is to take care of the competition that each tree in stands experiences.

The species that remained after the regression runs approximately coincided with the dominant species in the part of Alberta they mostly occur. The process of elimination by the number of plots, number of trees and by the 95% CI after the regression runs, did concentrate the major Alberta species onto the areas where they mostly occur. For example, VSR3 falls within the pine subregion of the subalpine ecoregion, where according to Strong and Leggat (1981), lodgepole pine occurs as the dominant species and spruce as the co-dominant species. This study comfirmed the dominance of pure lodgepole pine species in VSR3.

The study found lodgepole pine trees more likely to survive in mixed species stands than in pure species stands. That confirms the ecological expectation that because trees in pure stands have similar niches, they exert similar demands on the same resource. Thus competition for the resource is more intense in pure stands than it is in mixed stands and with more competition come more deaths in pure stands.

White spruce is more likely to survive in VSR3 than it is in VSR4. VSR4 is richer in species and generally more dense than higher elevation VSR3. Competition is likely to be greater in VSR4 than in VSR3 hence the greater probability of survival in VSR3 for white spruce. Balsam fir has a higher chance to survive in VSR4 than it has in VSR6. Balsam fir growing in VSR6 which is more northernly located experiences a severer growing environment than does balsam fir growing in VSR4. This may contribute to lower probability of survival for balsam in VSR6 as compared to balsam fir in VSR4. The higher probability of survival of black spruce in VSR5 as compared to black spruce in VSR4 might be due to higher incidence of competition in the denser VSR4.

5.1 Problems with data

The data that the AFS provided still contain considerable entry errors even though they have been edited since Morton and Titus (1984). This coupled with poor occurrence of some species in some VSRs presented considerable difficulty during the course of this study. In some cases a bias might have been introduced which affected the coefficients estimated. This might have been the case with white birch in VSR4 and other species whose coefficient estimates could assume a zero value.

5.2 Uses for the Study

Referring to the study objectives (section 1.3), the models could be used to estimate the probability that a tree belonging to a particular species growing in any of the VSRs in Alberta dies, which in turn could influence the calculation and projection of growing stock and therefore the allocation of allowable cut.

The evaluation of regional variations in mortality or survival probability made in this study would enable the AFS to plan different harvesting schedules for the same species growing in different VSRs if significant differences in mortality exist within the same species in different VSRs.

The evaluation performed for pure and mixed stands would enable the AFS to devise different management regimes for pure stands if the survival probability in pure stands differs significantly from that for mixed stands even for the same species.

By documenting the processes and the computer programs written to carry out this study, this study has made available to forest managers and scientists an additional procedure for summarizing PSP data and for estimating coefficients to advance further, the prediction of probability of survival or mortality for major Alberta species.

5.3 Recommendation

While almost all the acceptable coefficients could be used to obtain good survival predictions, there were a few that should be used with some caution. Generally, if the asymptotic 95% confidence limits associated with an estimated coefficient do not have opposite signs, then the estimated coefficient is highly significant. Table 10 shows some estimates with a chance of assuming a zero value for either their B or C estimates. Those coefficients were retained because the samples used to estimate them (coefficients) were sufficiently large and because those coefficients did not deviate much from those obtained by an almost similar study MGM (1990). It is important for the user to take note of and use those affected models with some caution.

It must be mentioned that where no significant probability difference was found between two groups for example, "4,6" Aw and "4,6" Bw, models developed for Aw and Bw in VSR4 cannot be used to manage Aw and Bw stands in VSR6 since the statistically insignificant differences could accumulate over wide area and over time. Even though theoritically a model developed for one group could be used to manage another group where the difference between the two groups are statistically insignificant, practically, better results would be obtained if a model is used to manage only the group for which it (the model) was developed.

6. CONCLUSION

It appears that in Alberta specific management schedules should be prepared for the same species occuring in different VSR. That 60% of the inter VSR comparisons exhibited significant differences (and these species are the major species in Alberta) calls for the development of specific mortality models for each species found in Alberta. This study has produced mortality models for six species which are applicable where indicated. More work has been recommended to develop more local models especially for those species which this study eliminated due to insufficient plots and or tree numbers in the VSRs that the study covered, and also for those species with insufficient data.

7. LITERATURE CITED

ALBERTA FOREST SERVICE PSP Field Procedure Manual.

ANDERSON, H. G. 1978. Biophysical Analysis and Evaluation of Capability--Castle River. Alberta Energy and Natural Resources, Edmonton, ALTA. Report No. 64.

------. 1979. Ecological Land Classification and Evaluation Highwood Sheep. Alberta Energy and Natural Resources Edmonton, ALTA. Report No. 93.

ARNEY, J. D. 1972. Computer simulation of Douglas fir tree and stand growth. Thesis for the Ph.D. degree, Oregon State University, Convallis Oregon.

AVERY, E. T. and H. E. BURKHART. 1983. Forest Measurements. (3rd edition). McGraw-Hill Book Company, New York.

BARNETT, V. 1983. Principles and methods for handling outliers in data sets. In Statistical methods and the implications of data quality. Academic Press, Sheffield, England.

BELLA, I. E. 1970. Simulation of growth, yield and management of aspen.Ph.D. Thesis. UBC., Vancouver.

BENNETT, F. A., C. E. McGEE, and J. L. CLUTTER. 1959. Yield of old field slash pine plantations. US.For. Ser., S.E. Forest Experimental Station. Paper No. 107.

BUCKMAN, R. E. 1962. Growth and yield of red pine in Minnesota. USDA. Techn. Bull. 1271.

CAULCOTT, E. 1973. Significance Test. Routledge and Kegan Paul Ltd, Broadway Hous [illegible]

CLUTTER, J. L. 1963. Compatible growth and yield models for Loblolly pine. For. Sci.,9: 354-371.

------- AND B. J. ALLISON. 1974. A growth model for Pinus radiata in New Zealand. In Growth models for tree and stand simulation. Royal College For Notes No.30, Stockholm.

-------. 1983. Timber Management: a quantitative approach. Wiley and Sons, New York. pp. 100-200.

------- AND E. P. JONES. 1980. Prediction of growth after thinning in old field slash pine plantations. U.S.D.A. For. Ser. Res. Paper SE-217.

COX, D. R. 1970. Analysis of binary data. Methuen, London.

DANIELS, R. F. AND H. E. BURKHART. 1975. Simulation of individual tree growth and stand development in managed loblolly pine plantations. Div. of For. and Wildlife Res., Va. Polytechnic Inst. and State Univ., FWS-5-75.

DAVIS, L. S. and K. N. JOHNSON. 1987. Forest Management. 3rd ed. McGraw-Hill Book, Toronto.

DRAPER, N. R. 1984. The Box-Wetz Criterion versus R-Sguared, J. R. Statistical Society, A 147, 100-103.

------ AND H. SMITH. 1966. Applied regression analysis. John Wiley and Sons, Inc., New York.

DRESS, P. E. 1970. A system for the stochastic simulation of even-aged forest stands of pure species composition. Thesis for the Ph.D. degree. Purdue Univ., Indiana.pp. 253.

EDELSTEIN-KESHET, L. 1988. Mathemetical models in biology. Random House, Inc., New York, New York.

GRIZZLE, J. E. C. F. STARMER AND G.G. KOCH. 1969. Analysis of catagorical data by linear models. Biometrics, 25, 489-504.

GROSENBAUGH, L. R. 1965. Generalization and reparamterization of some sigmoid and other nonlinear functions. Biometrics, 21: 708-714.

HAMILTON, D. A. 1974. Event probabilities estimated by regression. U.S.D.A. For. Serv. Res. Paper INT-152.

------ AND B. M. EDWARDS. 1976. Modeling the probability of individual tree mortality. U.S.D.A. Forest Service Research Paper INT-185.

------. 1980. Modeling mortality: a component of growth and yield modeling. P. 82-99 in Forcasting forest stand dynamics, proceedings of the workshop (Kenneth M. Brown and F. Richard Clarke, eds.) Forestry School, Lakehead University, Thunder Bay, Ont. Canada.

------. 1986. A logistic model of mortality in thinned and unthinned mixed conifer stands of Noethern Idaho. For. Sci. 32: 989-1000.

HANN, D. W. 1980. Development and evaluation of an even- and uneven aged ponderosa pine/Arizona fescue and simulator. U.S.D.A. For. Serv. Res. Paper INT-267.

HARNETT, D. L. 1970. Statistical Methods. 3rd edition, Addison-Wesley Publishing Company, Inc, Reading, Massachusetts.

HEALY, M. J. R. 1984. The Use of R-squared as a measure of Goodness of Fit. J. R. Statistical Soc., A 147,608-609.

HELLAND, I. S. 1987. On the Interpretation and Use of R^2 in Regression Analysis. Biometrics 43, 61-69.

HELLUM, A. K. 1967. Periodicity of height growth in white spruce reproduction. For. Chron. 43: 365-371.

HOSMER JR., D. W. AND LAMESHOW, S. Applied Logistic Regression. John Wiley and Sons, New York.

HUANG, S. AND S. J. TITUS. 1990. Permanent Sample Plots Data Summary Manual. Unpublished document prepared for the Dept. of Forest Science, University of Alberta, Edmonton.

HUNTSGERGER, D. V. AND P. P. BILLINGSLEY. 1987. Elements of Statistical Inference. 6th edition. Allyn and Bacon, Inc. Newton, Massachusetts.

HUSCH ET AL., 1972. Forest Mensuration. Ronald Press Co., New York, N. Y.

------. 1982. Forest Mensuration. 3rd edition. John Wiley and Sons, New York.

JENNRICH, R. I. AND M. L. RALSTON. 1979. Ann. Rev. Biophys. Bioeng. 8: 195-238.

LEE, Y. J.1971. Predicting mortality for even-aged stands of Lodgepole pine. For. Chron. 47: 29-32.

LEMON, G. L. 1975. Maximum likelihood estimation for the three parameter Weibull distribution based on censored samples. Technometric, Vol. 17, No. 2, pg. 247-254.

LIN, J. Y. 1970. Growing space index and stand simulation of young Western hemlock in Oregon. A Thesis for the Ph.D. degree. Duke University.

LITTLE, S. N. 1982. Weibull diameter distributions for mixed stands of western cornifers. Pacific Northwest Forest and Range Experimental Stn.,Portland, OR.

MADDALA, C. S. 1988. Introduction to econometrics. Macmillan Publishing Company, 866 Third Ave., New York.

MARSHALL, H. 1947. Longevity of American herring gull. Auk. 64: 188-198

McARDLE, R. E. 1949. The yield of Douglas fir in the Pacific Northwest. USDA. Techn. Bull. 201.

MEYER, H. A. 1053. Forest Mensuration. Penns Valley Publishers, Inc., State College, Pennsylvania.

MICHELLE, K. J. 1975. Dynamics and Simulated yield of Douglas fir. For Sci., Monograph No. 17.

MONSERUD, R. A. 1976. Simulation of forest tree mortality. For. Sci. 22: 438-444.

------- AND N. C CROOSTON. 1982. A user's guide to the combined stand prognosis and Douglas fir Tussock moth outbreak model. USDA For. Ser. Gen Tech. Rep. INT-127.

MORTON, R. AND S. J. TITUS. 1984. Mixedwood stand growth model. Univ. of Alberta. Edmonton.

------. 1990. MGM. Growth models developed for AFS.

MUNRO, D. D. 1974. Forest growth models- a prognosis. In

Growth models for tree and stand simulation. Royal Coll. For. Res. Notes No. 30. Stockholm.

NEWNHAM, R. M. 1964. The development of stand model for Douglas fir. A Thesis for the Ph.D. degree. UBC. Vancouver.

PFISTER, R. D., B. L. KOVALCHIK, S. F. ARNO, AND R. C. PRESBY. 1977. Forest Habitat Types of Montana. U.S. Department of Agriculture, Forest Service , Intermont. Forest Range Experimental stn., Ogden, Utah. General Technical Report INT-34.

PIENAAR, L. V. AND B. D. SHIVER. 1981. Survival functions for site prepared slash pine plantations in the flatwoods of Georgia and northern Florida. So. J. App. For. 5(2): 59-62.

PINDER ET AL., 1978. The Weibull distribution: A new method of summarizing survivorship data. Ecol. 59:175-179.

PRATT, J. W. 1981. Concavity of the log-likelihood. Journal of the American Statistical Association. pp. 137-159.

PRODAN, M. 1968. Forest Biometrics. Pergamon Press, Oxford.

RAMANATHAN, R. 1989. Introductory Econometrics with Applications. Harcourt Brace Jovanovich, Inc., Orlando, Florida. pp 400-420.

RATKOWSKY, D. A. 1983. Nonlinear regression. Marcel Dekker, Inc., N.Y.

-------. 1990. Handbook of Nonlinear Regression Models. Marcel Dekker, Inc., 270 Madison Avenue, N.Y. pp 44,45.

ROSS, R. L. AND H. E. HUNTER. 1976. Climax Vegetation of Based on Soils and climate. U.S. Dept. of Agric., Soil Conservation Service, Bozeman, Montana.

SAS PROCEDURES GUIDE. 1988. (Release 6.03 Edition) SAS Institute Inc., Cary, North Carolina.

SAS SYSTEM FOR REGRESSION. 1986. SAS Institute Inc., Cary, North Carolina

SAS USER'S GUIDE: BASICS. 1985. (Version 5) SAS Institute Inc., Cary, North Carolina.

SOMMERS ET AL., 1980. Predicting mortality with a Weibull distribution. For. Sci. 26: 291-300.

SMALLEY, G. W. AND R. L. BAILEY. 1974. Yield tables and stand structure for shortleaf pine plantations in Tennessee, Alabama, and Georgia highlands. U.S.D.A. For. Res. Paper SO-97.

SPURR, S. H. 1952. Forest Inventory. The Ronald Press Company, New York.

STAGE, A. R. 1973. Prognosis model for stand development. USDA Forest Service, Intermountain Forest and Range Experiment Station Research paper No. INT-137.

STRONG, W. L. 1979. Pre-and Postsettlement Polynology of Southern Alberta. Review of Paleobotany and Ploynology, 23: 373-387.

STRONG, W. L. AND LEGGAT, K. R. 1981. Ecoregions of Alberta, Ecological land classification and evaluation. Alberta Energy and Natural Resources, Resources

Evaluation and Planning Division.

THOMAS, C. E. AND B. R. PARESOL. 1989. Comparing basal area growth rates in repeated inventories: Simpson's paradox in forestry .For. Sci. 24: 47-56.

WRIGLEY, N. 1976. Introduction to the use of logit models in Geography. Concepts and Techniques in modern Geography. University of Bristol, England.

YANG, R. C., A. KOZAK, AND J. H. G. SMITH. 1978. The potential of Weibull-type functions as flexible growth curves. Can. J. For. Res. 8: 424-431.

APPENDIX I

A SAS PROGRAM TO SUMMARIZE INFORMATION ON VSR3, VSR4, VSR5 AND VSR6 TO DISTINGUISH BETWEEN MIXED PLOTS AND PURE PLOTS AND IDENTIFY CORRESPONDING PLOTS

```
      /*   VSR3  */;
CMS FILEDEF LINK DISK VSR3 DATA;

    /*DATA SET L13 IS SET UP TO RECEIVE THE PLOT CHARACTERISTIC FILE
      DEFINED AS LINK HOLDING PLOT SUMMARY DATA*/;

DATA L13;
   INFILE LINK;
   INPUT GRNUMB 1-4 PLNUMB 5 MEASNU 6 TRHAL 7-11 BAHPL 17-24
        TRHAS 30-34 BAHASC1 40-47 SPGRUP 59;
RUN;
     /*DATA SET SET UP TO RECEIVE INFORMATION READ FROM LINK*/;

DATA L23;
    SET L13;

   IF MEASNU > 0 THEN DELETE;
   IF PLNUMB > 1 THEN DELETE;
   IF TRNUMB=0000 OR TRNUMB=9998 THEN DELETE;
RUN;
    /*LIMIT DATA TO FIRST MEASUREMENT, AND FIRST PLOTS IN A GROUP.
      INGROWTHS AND SAPLINGS EXCLUDED*/;

   PROC SORT; BY SPGRUP;
RUN;

DATA L3; SET L23;
  PCTCOMP=100*BAHASC1/BAHPL;
  IF PCTCOMP=0 THEN PCTCOMP=0;
  IF PCTCOMP>0 AND PCTCOMP<10 THEN PCTCOMP=1;
  IF PCTCOMP>=10 AND PCTCOMP<20 THEN PCTCOMP=2;
  IF PCTCOMP>=20 AND PCTCOMP<30 THEN PCTCOMP=3;
  IF PCTCOMP>=30 AND PCTCOMP<40 THEN PCTCOMP=4;
  IF PCTCOMP>=40 AND PCTCOMP<50 THEN PCTCOMP=5;
  IF PCTCOMP>=50 AND PCTCOMP<60 THEN PCTCOMP=6;
  IF PCTCOMP>=60 AND PCTCOMP<70 THEN PCTCOMP=7;
  IF PCTCOMP>=70 AND PCTCOMP<80 THEN PCTCOMP=8;
  IF PCTCOMP>=80 THEN PCTCOMP=9;
RUN;
    /*CALCULATE PERCENTAGE OF SPECIES COMPOSITION BY BASAL AREA*/;

 PROC SORT DATA=L3; BY SPGRUP;
  RUN;

  DATA L3A;
    SET L3;
    PROC FREQ;
    TABLES SPGRUP*PCTCOMP;
  RUN;
     /*SUMMARIZES CALCULATED PERCENTAGES BY GROUPS*/;

 DATA L3B;
   SET L3;
   IF PCTCOMP > 8 THEN DELETE;
   PROC PRINT DATA=L3B;
```

```
  VAR GRNUMB SPGRUP BAHASC1 BAHPL PCTCOMP;
 RUN;
     /*ISOLATES MIXED STANDS*/;

 DATA L3C;
   SET L3;
   IF PCTCOMP < 9 THEN DELETE;
   PROC PRINT DATA=L3C;
  VAR GRNUMB SPGRUP BAHASC1 BAHPL PCTCOMP;
 RUN;
      /*ISOLATES PURE STANDS*/;
         /*VSR4
     SAME EXPLANATIONS AS ABOVE*/;


CMS FILEDEF LINK DISK VSR4 DATA;
DATA L14;
  INFILE LINK;
  INPUT GRNUMB 1-4 PLNUMB 5 MEASNU 6 TRHAL 7-11 BAHPL 17-24
       TRHAS 30-34 BAHASC1 40-47 SPGRUP 59;
RUN;

DATA L24;
   SET L14;

  IF MEASNU > 0 THEN DELETE;
  IF PLNUMB > 1 THEN DELETE;
  IF TRNUMB=0000 OR TRNUMB=9998 THEN DELETE;
RUN;

  PROC SORT; BY SPGRUP;
RUN;

DATA L4; SET L24;
 PCTCOMP=100*BAHASC1/BAHPL;
 IF PCTCOMP=0 THEN PCTCOMP=0;
 IF PCTCOMP>0 AND PCTCOMP<10 THEN PCTCOMP=1;
 IF PCTCOMP>=10 AND PCTCOMP<20 THEN PCTCOMP=2;
 IF PCTCOMP>=20 AND PCTCOMP<30 THEN PCTCOMP=3;
 IF PCTCOMP>=30 AND PCTCOMP<40 THEN PCTCOMP=4;
 IF PCTCOMP>=40 AND PCTCOMP<50 THEN PCTCOMP=5;
 IF PCTCOMP>=50 AND PCTCOMP<60 THEN PCTCOMP=6;
 IF PCTCOMP>=60 AND PCTCOMP<70 THEN PCTCOMP=7;
 IF PCTCOMP>=70 AND PCTCOMP<80 THEN PCTCOMP=8;
 IF PCTCOMP>=80 THEN PCTCOMP=9;

 PROC SORT DATA=L4, BY SPGRUP;
RUN;


DATA L4A,
    SET L4;
    PROC FREQ;
    TABLES SPGRUP*PCTCOMP;
RUN;

DATA L4B;
   SET L4;
   IF PCTCOMP > 8 THEN DELETE.
   PROC PRINT DATA=L4B;
   VAR GRNUMB SPGRUP BAHASC1 BAHPL PCTCOMP;
RUN;
```

```
DATA L4C;
    SET L4;
    IF PCTCOMP < 9 THEN DELETE;
    PROC PRINT DATA=L4C;
    VAR GRNUMB SPGRUP BAHASC1 BAHPL PCTCOMP;
RUN;


        /*VSR5*/

CMS FILEDEF LINK DISK VSR5 DATA;
DATA L15;
   INFILE LINK;
   INPUT GRNUMB 1-4 PLNUMB 5 MEASNU 6 TRHAL 7-11 BAHPL 17-24
         TRHAS 30-34 BAHASC1 40-47 SPGRUP 59;
RUN;

DATA L25;
    SET L15;

   IF MEASNU > 0 THEN DELETE;
   IF PLNUMB > 1 THEN DELETE;
   IF TRNUMB=0000 OR TRNUMB=9998 THEN DELETE;
   RUN;

   PROC SORT; BY SPGRUP;
RUN;

DATA L5; SET L25;
  PCTCOMP=100*BAHASC1/BAHPL;
  IF PCTCOMP=0 THEN PCTCOMP=0;
  IF PCTCOMP>0 AND PCTCOMP<10 THEN PCTCOMP=1;
  IF PCTCOMP>=10 AND PCTCOMP<20 THEN PCTCOMP=2;
  IF PCTCOMP>=20 AND PCTCOMP<30 THEN PCTCOMP=3;
  IF PCTCOMP>=30 AND PCTCOMP<40 THEN PCTCOMP=4;
  IF PCTCOMP>=40 AND PCTCOMP<50 THEN PCTCOMP=5;
  IF PCTCOMP>=50 AND PCTCOMP<60 THEN PCTCOMP=6;
  IF PCTCOMP>=60 AND PCTCOMP<70 THEN PCTCOMP=7;
  IF PCTCOMP>=70 AND PCTCOMP<80 THEN PCTCOMP=8;
  IF PCTCOMP>=80 THEN PCTCOMP=9;

PROC SORT DATA=L5; BY SPGRUP;
RUN;
   DATA L5A;
     SET L5;
     PROC FREQ;
     TABLES SPGRUP*PCTCOMP;
RUN;

DATA L5B;
    SET L5;
    IF PCTCOMP > 8 THEN DELETE;
    PROC PRINT DATA=L5B;
    VAR GRNUMB SPGRUP BAHASC1 BAHPL PCTCOMP;
RUN;

DATA L5C;
    SET L5;
    IF PCTCOMP < 9 THEN DELETE;
    PROC PRINT DATA=L5C;
    VAR GRNUMB SPGRUP BAHASC1 BAHPL PCTCOMP;
```

```
RUN;

        /*VSR6*/

CMS FILEDEF LINK DISK VSR6 DATA;
 DATA L16;
  INFILE LINK;
  INPUT GRNUMB 1-4 PLNUMB 5 MEASNU 6 TRHAL 7-11 BAHPL 17-24
       TRHAS 30-34 BAHASC1 40-47 SPGRUP 59;
RUN;

DATA L26;
    SET L16;

  IF MEASNU > 0 THEN DELETE;
  IF PLNUMB > 1 THEN DELETE;
  IF TRNUMB=0000 OR TRNUMB=9998 THEN DELETE;
  RUN;

  PROC SORT; BY SPGRUP;
RUN;

DATA L6; SET L26;
 PCTCOMP=100*BAHASC1/BAHPL;
 IF PCTCOMP=0 THEN PCTCOMP=0;
 IF PCTCOMP>0 AND PCTCOMP<10 THEN PCTCOMP=1;
 IF PCTCOMP>=10 AND PCTCOMP<20 THEN PCTCOMP=2;
 IF PCTCOMP>=20 AND PCTCOMP<30 THEN PCTCOMP=3;
 IF PCTCOMP>=30 AND PCTCOMP<40 THEN PCTCOMP=4;
 IF PCTCOMP>=40 AND PCTCOMP<50 THEN PCTCOMP=5;
 IF PCTCOMP>=50 AND PCTCOMP<60 THEN PCTCOMP=6;
 IF PCTCOMP>=60 AND PCTCOMP<70 THEN PCTCOMP=7;
 IF PCTCOMP>=70 AND PCTCOMP<80 THEN PCTCOMP=8;
 IF PCTCOMP>=80 THEN PCTCOMP=9;

 PROC SORT DATA=L6; BY SPGRUP;
 RUN;
DATA L6A;
    SET L6;
    PROC FREQ;
    TABLES SPGRUP*PCTCOMP;
RUN;

DATA L6B;
   SET L6;
   IF PCTCOMP > 8 THEN DELETE;
   PROC PRINT DATA=L6B;
   VAR GRNUMB SPGRUP BAHASC1 BAHPL PCTCOMP;
RUN;

DATA L6C;
    SET L6;
    IF PCTCOMP < 9 THEN DELETE;
    PROC PRINT DATA=L6C;
    VAR GRNUMB SPGRUP BAHASC1 BAHPL PCTCOMP;
RUN;
```

The SAS System

APPENDIX II CONTINUED: VSR3 (MIXED)

OBS	GRNUMB	SPGRUP	BAHASC1	BAHPL	PCTCOMP
1	101	1	0.0126	31.1371	1
2	103	1	0.4608	21.9475	1
3	104	1	16.8014	33.1395	6
4	111	1	2.0104	17.0428	2
5	112	1	20.7844	42.0928	5
6	113	1	20.2365	35.5050	6
7	114	1	13.4423	53.8329	3
8	115	1	12.9270	29.0888	5
9	116	1	14.2526	26.4666	6
10	118	1	32.4509	41.4264	8
11	119	1	21.8987	37.4333	6
12	120	1	21.1026	53.1165	4
13	121	1	6.0291	46.7340	2
14	123	1	14.3176	44.2197	4
15	127	1	25.6963	45.3864	6
63	125	5	0.4930	33.9942	1
64	128	5	17.2881	53.4960	4
65	153	5	1.0220	33.3281	1
66	565	5	0.118[illegible]	2.8324	1
67	104	6	3.2307	33.1395	1
68	111	6	0.0734	17.0428	1
69	112	6	9.0573	42.0928	3
70	113	6	3.1463	35.5050	1
71	114	6	0.8403	53.8329	1
72	115	6	0.1468	29.0888	1
73	118	6	0.1218	41.4264	1
74	123	6	29.9021	44.2197	7
75	141	6	0.1798	43.9014	1
76	142	6	15.5686	33.3253	5
77	143	6	4.8493	43.2108	2

The SAS System

(PURE)

OBS	GRNUMB	SPGRUP	BAHASC1	BAHPL	PCTCOMP
1	122	1	30.378[illegible]	31.9940	9
2	124	1	16.5695	17.4123	9
3	125	1	27.2793	33.9942	9
4	126	1	38.6714	39.4091	9
5	143	1	35.1590	43.2108	9
6	101	2	30.0609	31.1371	9
25	557	2	39.3211	39.3211	9
26	562	2	24.9451	24.9451	9
27	563	2	21.5152	21.5152	9
28	564	2	19.1555	19.1555	9
29	565	2	2.5917	2.8324	9

The SAS System

APPENDIX II CONTINUED: VSR4 (MIXED)

OBS	GRNUMB	SPGRUP	BAHASC1	BAHPL	PCTCOMP
1	1	1	19.[illegible]25	43.5129	5
2	2	1	27.3352	42.9112	7
3	3	1	0.0062	33.3500	1
4	4	1	10.4768	48.6277	3
5	5	1	17.4596	47.2377	4
6	6	1	0.8082	42.3495	2
7	7	1	4.4189	42.8931	2
8	8	1	0.4556	40.5234	1
9	9	1	1.3769	32.7817	1
10	10	1	0.0439	24.2215	1
11	11	1	8.0840	30.9579	3
12	12	1	18.9780	34.5504	6
13	13	1	3.6552	28.6939	2
14	14	1	0.0573	13.6943	1
15	15	1	4.3685	42.3334	2
[illegible]	242	6	14.1050	48.6073	3
[illegible]	249	6	0.8808	41.1675	1
[illegible]	252	6	0.6657	50.5128	1
[illegible]	256	6	1.2633	47.6041	1
[illegible]	[illegible]	6	2.3779	9.1084	3
346	[illegible]	6	0.3613	24.7991	1
347	[illegible]59	6	6.8342	38.5853	2
348	909	6	12.1493	17.0528	8
349	911	6	7.0804	12.2382	6
350	912	6	14.4665	20.9591	7
351	914	6	11.2597	19.9710	6
352	919	6	1.6232	2.7006	7
353	922	6	5.6308	7.2133	8
354	923	6	2.1335	6.2391	4
355	924	6	1.8983	4.9151	4

The SAS System

(PURE)

OBS	GRNUMB	SPGRUP	BAHASC1	BAHPL	PCTCOMP
1	198	1	36.1769	44.9116	9
2	255	1	36.1501	36.1501	9
3	256	1	54.4739	63.9464	9
4	257	1	50.5889	56.3416	9
5	545	1	22.4347	22.6796	9
74	918	6	2.8960	2.8960	9
75	920	6	1.5146	1.5146	9
76	921	6	0.8665	0.8665	9
77	930	6	1.8502	1.8502	9

The SAS System

APPENDIX II CONTINUED: VSRS (MIXED)

OBS	GRNUMB	SPGRUP	BAHASC1	BAHPL	PCTCOMP
1	56	1	0.3379	48.6502	1
2	64	1	28.7565	39.6586	8
3	66	1	18.4732	32.1988	6
4	71	1	1.0823	16.7341	1
5	72	1	0.2016	14.5403	1
6	73	1	1.8930	19.7684	1
7	74	1	0.0024	13.2599	1
8	79	1	0.0023	24.1709	1
9	80	1	0.7971	23.8130	1
10	82	1	0.1189	45.8484	1
11	89	1	0.5639	29.9712	1
12	90	1	8.59[illegible]	11.5495	2
13	462	1	16.3980	37.3632	5
14	463	1	8.8705	36.2110	3
15	464	1	6.2797	28.1725	3
67	79	5	0.9192	24.1709	1
68	80	5	3.5755	23.8130	2
69	81	5	32.2713	47.3159	7
70	82	5	4.1827	45.8484	1
71	83	5	17.8138	51.8469	4
72	84	5	7.9445	37.0706	3
73	86	5	0.0461	33.0669	1
74	89	5	7.4525	29.9712	3
75	462	5	1.3871	37.3632	1
76	64	6	10.0324	39.6586	3
77	66	6	9.7202	32.1988	4
78	67	6	1.8052	21.5449	1
79	90	6	1.3222	11.5495	2
80	462	6	0.2802	37.3632	1

The SAS System

(PURE)

OBS	GRNUMB	SPGRUP	BAHASC1	BAHPL	PCTCOMP
1	67	1	18.4828	21.5449	9
2	55	2	32.4028	32.4028	9
3	56	2	25.4385	2[illegible]	[illegible]
4	57	2	29.2026	29.[illegible]	[illegible]
5	59	2	34.3602	38.3094	9
6	60	2	29.4719	32.4681	9
17	80	2	19.4404	23.8130	[illegible]
18	82	2	41.5468	45.8484	9
19	87	2	32.2705	[illegible]2.9494	9
20	88	2	35.5892	[illegible].5892	9
21	72	4	13.6045	14.5403	9

The SAS System

APPENDIX II CONTINUED: VSR6 (MIXED)

OBS	GRNUMB	SPGRUP	BAHASC1	BAHPL	PCTCOMP
1	45	1	7.0239	38.4364	2
2	48	1	0.2706	18.9189	1
3	50	1	23.9472	54.9336	5
4	52	1	17.8234	57.6323	4
5	53	1	26.9966	44.5590	7
6	259	1	22.1938	40.6288	6
7	260	1	18.7365	37.1567	6
8	261	1	29.1783	44.6929	7
9	262	1	13.6443	36.8847	6
10	263	1	18.8292	42.5979	5
11	264	1	26.7944	45.1785	6
12	265	1	36.6208	46.8862	8
13	267	1	17.7550	45.8251	4
14	268	1	23.7265	37.9900	7
15	269	1	18.3455	52.7883	4
256	270	6	0.6239	45.8493	1
257	274	6	1.2779	38.5723	1
258	275	6	0.8874	50.4973	1
259	277	6	0.0273	43.5942	1
260	280	6	6.5869	46.0162	2
261	282	6	21.9061	51.4991	5
262	283	6	9.7261	35.2695	3
263	298	6	4.6676	36.2335	2
264	301	6	4.8716	25.4753	2
265	302	6	2.6719	35.2269	1
266	342	6	1.7831	52.4848	1
267	343	6	8.6803	44.6037	2
268	346	6	4.7105	46.4290	2
269	347	6	2.8302	50.9345	1

The SAS System

(PURE)

OBS	GRNUMB	SPGRUP	BAHASC1	BAHPL	PCTCOMP
1	46	1	33.2806	37.7092	9
2	266	1	31.6723	38.5527	9
3	290	1	44.6192	51.1610	9
4	298	1	31.3233	36.2335	9
5	303	1	37.9585	46.1928	9
6	345	1	40.5930	47.8714	9
13	44	3	21.7383	24.6287	9
14	54	3	30.0400	34.8740	9
15	295	3	29.0488	30.3143	9
16	48	4	16.9797	18.9189	9
17	51	4	24.0241	29.4078	9

APPENDIX III

SAS PROGRAM WRITTEN TO PROCESS AFS DATA AND TO DO REGRESSION RUNS

NOTE: '/* and */' ENCLOSES EXPLANATORY STATEMENTS*/;

```
CMS FILEDEF OB TAP1 SL (RECFM FB LRECL 100 BLOCK 23400;
    /*READS AFS DATA DIRECTLY FROM TAPE AS FILE OB*/;

CMS FILEDEF LINK DISK VSR4 DATA;
    /*READS TREE AND PLOT DATA FILE LINK FOR VSR4 FROM A GROUP OF FILES*/;
DATA L1;
    /*DATA SET L1 IS SET UP TO RECEIVE THE PLOT CHAR FILE DEFINED AS LINK*/;

  INFILE LINK;
  INPUT GRNUMB 1-4 PLNUMB 5 MEASNU 6 TRHAL 7-11 BAHPL 17-24
      TRHAS 30-34 RETYPE 36-37 BAHASC1 40-47 SPGRUP 59;
RUN;
  /*DIRECT SAS TO WHICH COLUMNS/VARIABLES TO READ INTO L1. FOR
   DEFINITION OF ABOVE VARIABLES REFER TO 'PSP DATA SUMMARY MANUAL'
   HUANG AND TITUS (1990)*/;

DATA A;
  INFILE OB;
    /*DATA SET 'A' IS SET UP TO RECEIVE THE PSP RAW DATA ON TAPE NAMED OB*/;

   INPUT RETYPE 36-37 @; RETAIN PLSIZE;

    /*RETYPE=1 IS TREE CHARACTERISTICS
      RETYPE=2 IS PLOT CHARACTERISTICS
      RETYPE=3 IS INGROWTH CHARACTERISTICS*/;

   IF RETYPE = 1 THEN DO;
      INPUT GRNUMB 3-12 PLNUMB 13 MEASNU 14-15 YEAR 16-17 UNITS 35
      RETYPE 36-37 PLSIZE 38-42;
   END;
   IF RETYPE =2 THEN DO;
    INPUT AGENCY 1-2 GRNUMB 3-12 PLNUMB 13 MEASNU 14-15 YEAR 16-17
       MONTH 18-19 RETYPE 36-37 TRNUMB 38-41 SPCODE $ 42-43 DBH 44-47 .1
        CONDIT1 57-58 CONDIT2 59-60 CONDIT3 61-62;
   END;

/*
 IF GRNUMB<101 THEN DELETE;
 IF GRNUMB>107 AND GRNUMB<111 THEN DELETE;
 IF GRNUMB>128 AND GRNUMB<141 THEN DELETE;
 IF GRNUMB>146 AND GRNUMB<151 THEN DELETE;
 IF GRNUMB>154 AND GRNUMB<164 THEN DELETE;
 IF GRNUMB>166 AND GRNUMB<557 THEN DELETE;
 IF GRNUMB>557 AND GRNUMB<565 THEN DELETE;
 IF GRNUMB>565 THEN DELETE; */
   /*ABOVE ISOLATES VSR3*/


 IF GRNUMB>43 AND GRNUMB<181 THEN DELETE;
 IF GRNUMB>214 AND GRNUMB<226 THEN DELETE;
 IF GRNUMB>258 AND GRNUMB<352 THEN DELETE;
 IF GRNUMB>359 AND GRNUMB<365 THEN DELETE;
 IF GRNUMB>366 AND GRNUMB<388 THEN DELETE;
 IF GRNUMB>399 AND GRNUMB<423 THEN DELETE;
 IF GRNUMB>425 AND GRNUMB<457 THEN DELETE;
```

```
IF GRNUMB>459 AND GRNUMB<545 THEN DELETE;
IF GRNUMB>546 AND DRNUMB<584 THEN DELETE;
IF GRNUMB>585 AND GRNUMB<599 THEN DELETE;
IF GRNUMB>610 AND GRNUMB<615 THEN DELETE;
IF GRNUMB>615 AND GRNUMB<901 THEN DELETE;
IF GRNUMB>9[illegible]4 AND GRNUMB<930 THEN DELETE;
IF GRNUMB>938 THEN DELETE;
  /*THIS DEFINES VSR4*/


/*
 IF GRNUMB<55 THEN DELETE;
 IF GRNUMB>90 AND GRNUMB<361 THEN DELETE;
 IF GRNUMB>361 AND GRNUMB<462 THEN DELETE;
 IF GRNUMB>464 AND GRNUMB<602 THEN DELETE;
 IF GRNUMB>602 THEN DELETE; */
   /*THIS DEFINES VSR5*/


/*
 IF GRNUMB<44 THEN DELETE;
 IF GRNUMB>54 AND GRNUMB<259 THEN DELETE;
 IF GRNUMB>303 AND GRNUMB<338 THEN DELETE;
 IF GRNUMB>351 AND GRNUMB<466 THEN DELETE;
 IF GRNUMB>468 AND GRNUMB<471 THEN DELETE;
 IF GRNUMB>474 AND GRNUMB<494 THEN DELETE;
 IF GRNUMB>498 AND GRNUMB<600 THEN DELETE;
 IF GRNUMB>600 THEN DELETE; */
   /*THIS ISOLATES VSR6*/

 /*THESE GROUPS NUMBERS DEFINE AND ISOLATE VSR4 IN THE FILE OB*/;

IF MEASNU > 4 THEN DELETE;
  /*GIVES FOUR CONSECUTIVE MEASUREMENTS. THIS ALLOWS THE STUDY
    OF HOW INDIVIDUAL TREES ARE DOING FOR A LONG TIME.*/;

IF RETYPE=3 THEN DELETE;
IF PLNUMB > 1 THEN DELETE;
  /*GIVES FIRST PLOTS OF EACH GROUP*/;

IF SPCODE NE 'PI' THEN DELETE;
  /*Sw, Bw, PI, Sb, Aw AND Fb ARE INDIVIDUALY USED IN EACH RUN
    DEPENDING ON WHICH SPECIES IS BEING PROCESSED*/;

IF TRNUMB=00 OR TRNUMB=0000 OR TRNUMB=9998 THEN DELETE;
    /*ELIMINATES SAPLINGS, AND INGROWTHS*/

 BA=0.00007854*(DBH)**2;
 BAH=10000*BA/PLSIZE;
 IF DBH>0 THEN
 DCLASS=INT(DBH/2.5)+1;
 IF DBH>45.0 THEN
 DCLASS=INT(DBH/5.0)+1;
 IF DBH>50.0 THEN
 DCLASS=INT(DBH/10.0)+1;
  /*BA IS THE AREA OCCUPIED BY A SINGLE TREE IN THE PLOT WHEN BA
    IS PROJECTED OVER A HACTARE, THE AREA IS CALLED BAH.DIAMETER
    CLASSES (DCLASS) ARE DESIGNED ACCORDING TO MORTON AND TITUS (1986)*/;

 IF DBH>0 THEN DBHMDPT=1.25;
 IF DBH>2.5 THEN DBHMDPT=3.75;
 IF DBH>5.0 THEN DBHMDPT=6.25;
```

```
IF DBH>7.5 THEN DBHMDPT=8.75;
IF DBH>10.0 THEN DBHMDPT=11.25;
IF DBH>12.5 THEN DBHMDPT=13.75;
IF DBH>15.0 THEN DBHMDPT=16.25;
IF DBH>17.5 THEN DBHMDPT=18.75;
IF DBH>20.0 THEN DBHMDPT=21.25;
IF DBH>22.5 THEN DBHMDPT=23.75;
IF DBH>25.0 THEN DBHMDPT=26.25;
IF DBH>27.5 THEN DBHMDPT=28.75;
IF DBH>30.0 THEN DBHMDPT=31.25;
IF DBH>32.5 THEN DBHMDPT=33.75;
IF DBH>35.0 THEN DBHMDPT=36.25;
IF DBH>37.5 THEN DBHMDPT=38.75;
IF DBH>40.5 THEN DBHMDPT=41.25;
IF DBH>42.5 THEN DBHMDPT=43.75;
IF DBH>45.0 THEN DBHMDPT=47.50;
IF DBH>50.0 THEN DBHMDPT=50.00;
   /*ASSIGN MIDPOINTS (DBHMDPT) TO THE DIAMETER CLASSES*/;

RUN;

 /*DATA SET B CONTAINS ALL THE RAW PSP DATA EXCEPT MONTH WHICH IS
   ADJUSTED AS BELOW AND CONDTION CODE 25,27 WHICH ARE REPLACED
   WITH A '.'. THIS IS NECESSARY TO PREVENT ERRONEOUS MEANS CALCULATION*/;

DATA B; SET A;
IF MONTH=1 OR MONTH=2 OR MONTH=3 OR MONTH=4 THEN MONTH=0;
IF MONTH=5 THEN MONTH=0.2;
IF MONTH=6 THEN MONTH=0.5;
IF MONTH=7 THE[illegible] 0.9;
IF MONTH=8 C[illegible] OR MONTH=10 OR MONTH=11
OR MONTH=12 T[illegible]H=1.0;
   /*ADJUST DIAMETER ACCORDING TO SEASON*/;

 IF CONDIT1=25 OR CONDIT1=27 THEN DBH=.;
 IF CONDIT2=25 OR CONDIT2=27 THEN DBH=.;
 IF CONDIT3=25 OR CONDIT2=27 THEN DBH=.;
   /*REPLACES '0' WITH '.' TO OBTAIN CORRECT MEANS*/;

 RUN;

DATA A1;
   SET B;
    DBH1=DBH; DCLASS1=DCLASS; BAH1=BAH; YEAR1=YEAR; MONTH1=MONTH;
      DBHMDPT1=DBHMDPT; COND1=CONDIT1;
   IF MEASNU=0; OUTPUT A1; RUN;

DATA A2;
   SET B;
    DBH2=DBH; DCLASS2=DCLASS; BAH2=BAH; YEAR2=YEAR; MONTH2=MONTH;
      DBHMDPT2=DBHMDPT; COND2=CONDIT1;
   IF MEASNU=1; OUTPUT A2; RUN;

DATA A3;
     SET B;
     DBH3=DBH, DCLASS3=DCLASS; BAH3=BAH; YEAR3=YEAR; MONTH3=MONTH;
     DBHMDPT3=DBHMDPT; COND3=CONDIT1;
     IF MEASNU=2; OUTPUT A3; RUN;

DATA A4;
    SET B;
    DBH4=DBH; DCLASS4=DCLASS; BAH4=BAH; YEAR4=YEAR; MONTH4=MONTH;
```

```
        DBHMDPT4=DBHMDPT; COND4=CONDIT1;
   IF MEASNU=3; OUTPUT A4; RUN;

DATA A5;
     SET B;
    DBH5=DBH; DCLASS5=DCLASS; BAH5=BAH; YEAR5=YEAR; MONTH5=MONTH;
        DBHMDPT5=DBHMDPT; COND5=CONDIT1;
    IF MEASNU=4; OUTPUT A5; RUN;
       /*DATA SETS A1-A5 ARE SET UP TO CONTAIN TREE INFORMATION AT
         MEASUREMENTS 0-4 RESPECTIVELY*/

   PROC SORT DATA=A1; BY GRNUMB TRNUMB;
   PROC SORT DATA=A2; BY GRNUMB TRNUMB;
   PROC SORT DATA=A3; BY GRNUMB TRNUMB;
   PROC SORT DATA=A4; BY GRNUMB TRNUMB;
   PROC SORT DATA=A5; BY GRNUMB TRNUMB;

DATA B1;
  MERGE A1 A2 A3 A4 A5; BY GRNUMB TRNUMB;
    /*B1 CONTAINS A1-A5 MERGED INTO A SINGLE DATA FILE*/;

DATA C; SET B1;
   /*C IS SET UP TO CONTAIN ONLY THE VARS THAT WILL BE NEEDED FOR
     FURTHER WORK. THESE VARS ARE INTRODUCED BY THE KEEP COMMAND*/;

 KEEP GRNUMB TRNUMB DBH1 DBH2 DBH3 DBH4 DBH5 BAH1 BAH2 BAH3
     BAH4 BAH5 COND1 COND2 COND3 COND4 COND5 YEAR1 MONTH1 YEAR2
     MONTH2 YEAR3 MONTH3 YEAR4 MONTH4 YEAR5 MONTH5 DCLASS1
     DCLASS2 DCLASS3 DCLASS4 DCLASS5 DCLASS DBH DBHMDPT1 DBHMDPT2
     DBHMDPT3 DBHMDPT4 DBHMDPT5;
 RUN;

DATA C2; SET C;
    /*C2 IS SET UP TO CONTAIN THE VARIOUS MEASUREMENT INTERVALS
      REFERRED TO AS LOGPD1-LOGPD4*/;

   YINT1=YEAR2-YEAR1;
   INTL1=MONTH2-MONTH1;
   YINT2=YEAR3-YEAR2;
   INTL2=MONTH3-MONTH2;
   YINT3=YEAR4-YEAR3;
   INTL3=MONTH4-MONTH3;
   YINT4=YEAR5-YEAR4;
   INTL4=MONTH5-MONTH4;

   LOGPD1=YINT1+INTL1;
   LOGPD2=YINT2+INTL2;
   LOGPD3=YINT3+INTL3;
   LOGPD4=YINT4+INTL4;

   IF TRNUMB=. THEN DELETE;
   IF LOGPD1=. AND LOGPD2=. THEN DELETE;
   IF COND1=77 OR COND2=77 OR COND3=77 OR COND4=77 OR COND5=77
   THEN DELETE;
      /*TO GET RID OF THE FIRST LINE AND TO DELETE ALL INFO ABOUT
        TREES WITH CONDITION CODE 77*/;

  PROC PRINT DATA=C2; VAR GRNUMB TRNUMB DBH1 DCLASS1 LOGPD1
      COND1 DBH2 DCLASS2 LOGPD COND2;

        /*DBHMDPT3 LOGPD2 COND3
          DBHMDPT4 LOGPD3 COND4
```

```
        DBHMDPT5 LOGPD4 COND5;*/
  RUN;
    /*THIS PRINTS APPENDIX IV*/;

 PROC SORT DATA=C2; BY DCLASS1 GRNUMB;
 RUN;

 PROC MEANS DATA=C2 NOPRINT;
  VAR DBHMDPT1 DBHMDPT2 DBHMDPT3 DBHMDPT4 DBHMDPT5
   LOGPD1 LOGPD2 LOGPD3 LOGPD4;
  BY DCLASS1 GRNUMB;
  OUTPUT OUT=C3 MEAN=MD1 MD2 MD3 MD4 MD5 L1 L2 L3 L4 N=N1 N2 N3  N4 N5
       LN1 LN2 LN3 LN4;
   /*THE MEANS PROCEDURE IS USED TO OBTAIN THE # OF OBS.
     IN EACH DCLASS USING THE MIDPOINTS(DBHMDPT)*/;
   RUN;

DATA C4; SET C3;
    /*C3 PUT INTO C4 CONTAINS THE # OF TREES ALIVE AT EACH MEASUREMENT*/

 IF MD1=. THEN DELETE;
 RUN;

DATA C5;
 SET C4; PROC SORT; BY GRNUMB;
   RUN;
    /*C5 IS CREATED TO HOLD C4 LATER TO BE MERGED WITH BASAL AREA
      CHARACTERISTICS FILE (LINK1)*/;

DATA LINK1;
   /*LINK1 IS MADE TO HOLD PLOT CHARACTERISTICS DATA SET L1
     READ FROM FILE PREPARED HUANG AND TITUS 1990)*/;

  SET L1;

 IF GRNUMB>43 AND GRNUMB<181 THEN DELETE;
 IF GRNUMB>214 AND GRNUMB<226 THEN DELETE;
 IF GRNUMB>258 AND GRNUMB<352 THEN DELETE;
 IF GRNUMB>359 AND GRNUMB<365 THEN DELETE;
 IF GRNUMB>366 AND GRNUMB<388 THEN DELETE;
 IF GRNUMB>399 AND GRNUMB<423 THEN DELETE;
 IF GRNUMB>425 AND GRNUMB<457 THEN DELETE;
 IF GRNUMB>459 AND GRNUMB<545 THEN DELETE;
 IF GRNUMB>546 AND DRNUMB<584 THEN DELETE;
 IF GRNUMB>585 AND GRNUMB<599 THEN DELETE;
 IF GRNUMB>610 AND GRNUMB<615 THEN DELETE;
 IF GRNUMB>615 AND GRNUMB<901 THEN DELETE;
 IF GRNUMB>924 AND GRNUMB<930 THEN DELETE;
 IF GRNUMB>938 THEN DELETE;
    /*ISOLATES VSR4 FROM OTHERS IN LINK
      OTHER VSRS ARE TYPED HERE AS NEEDED*/


IF MEASNU > 0 THEN DELETE;
  /*BASAL AREA PER HA OF ALL SPECIES AT FIRST MEASUREMENT IS NEEDED*/;

 IF SPGRUP NE 1 THEN DELETE;
  /*SPECIES GROUP 1 IN LINK REFERS TO SW. GROUPS RUN FROM 1-6 AS FOLLOWS:
          GROUP         SPECIES
            1         WHITE SPRUCE
            2         LODGEPOLE PINE
            3         ASPEN
```

```
                4          WHITE BIRCH
                5          BLACK SPRUCE
                6          BALSAM FIR
             */;

RUN;

DATA M1B;
   MERGE C5 LINK1; BY GRNUMB;
   /*C5 WHICH IS C5 SORTED BY GRNUMB IS MERGED WITH LINK1
     CONTAINING PLOT CHARACTERISTIC BAHPL BY GRNUMB AND PUT INTO M1B*/;

   IF DCLASS1=. THEN DELETE;
   RUN;

 /*ABOVE COMPLETES THE ORGANIZATION OF DATA NECESSARY FOR THE
    LOGISTIC REGRESSION.

   TO DEFINE VARS FOR THE NLIN PROCEDURE, # OF TREES AT SECOND MEASUREMENT
   ARE ASSIGNED Y=1 (1 BEING SURVIVOR) NON-SURVIVORS (0 BEING NON-SURVIVOR)
   ARE OBTAINED BY N1-N2. THE COUNT COMMAND GIVES THE # OF 1'S AND 0'S AT
   THE END OF THE SECOND  MEASUREMENT.*/;

DATA LM; SET M1B;
  COUNT=N2; Y=1; OUTPUT;
  COUNT=N1-N2; Y=0; OUTPUT;
  RUN;

DATA LMOD;
   SET LM;
   IF COUNT=0 THEN COUNT=.;
   PROC PRINT DATA=LMOD;
   VAR GRNUMB DCLASS1 MD1 BAHPL L1 N1 N2 COUNT Y;
    /*THE FINAL DATA SET IS LMOD. THIS IS THE DATA FILE USED IN THE
      REGRESSION RUNS. THE SAMPLE LISTING OF LMOD IS SHOWN AS
      APPENDIX IV(B)*/;
RUN;

   PROC NLIN DATA=LMOD;
        PARMS A 2 6
             B .04 .4
             C 0;
        Y=(1+EXP(-(A+B*MD1+C*BAHPL)))**-L1;
  _WEIGHT_=COUNT;
RUN;
```

APPENDIX IV: SAMPLE LISTING OF FINAL DATA SET USED IN REGRESSION RUNS (Sb VSR4)

The SAS System

OBS	GRNUMB	DCLASS1	MD1	BAHPL	L1	N1	N2	COUNT	Y
57	40	2	3.6000	44.2169	7.0	50	36	36	1
58	40	3	6.2500	44.2169	7.0	40	36	36	1
59	40	4	8.7500	44.2169	7.0	60	60	60	1
60	40	5	11.2500	44.2169	7.0	58	58	58	1
61	40	6	13.7500	44.2169	7.0	22	21	21	1
62	40	7	15.6250	44.2169	7.0	4	4	4	1
63	40	8	18.7500	44.2169	7.0	1	1	1	1
64	42	1	1.2500	45.3361	6.7	3	0	.	1
65	42	2	3.5904	45.3361	6.7	47	35	35	1
66	42	3	6.2500	45.3361	6.7	71	68	68	1
67	42	4	8.7500	45.3361	6.7	108	108	108	1
68	42	5	11.2500	45.3361	6.7	54	54	54	1
69	42	6	13.7500	45.3361	6.7	12	12	12	1
70	42	7	16.2500	45.3361	6.7	1	1	1	1
71	181	3	6.2500	33.7390	19.0	1	1	1	1
72	181	4	8.7500	33.7390	19.0	3	3	3	1
73	181	5	11.2500	33.7390	19.0	2	2	2	1
74	181	6	13.7500	33.7390	19.0	1	1	1	1
75	182	2	2.5000	30.7342	14.0	2	2	2	1
76	182	3	6.2500	30.7342	14.0	1	1	1	1
77	182	4	8.7500	30.7342	14.0	2	2	2	1
78	185	1	1.2500	42.9228	14.0	2	2	2	1
79	185	2	3.5714	42.9228	14.0	28	27	27	1
80	185	3	6.2500	42.9228	14.0	32	32	32	1
81	185	4	8.7500	42.9228	14.0	22	22	22	1
82	185	5	11.2500	42.9228	14.0	3	3	3	1
83	186	1	1.2500	38.0211	14.0	13	13	13	1
84	186	2	3.6310	38.0211	14.0	21	21	21	1
85	186	3	6.2500	38.0211	14.0	20	20	20	1
86	186	4	8.7500	38.0211	14.0	14	14	14	1
87	186	5	11.2500	38.0211	14.0	11	11	11	1
88	186	6	13.7500	38.0211	14.0	2	2	2	1
89	187	1	1.2500	49.8705	14.1	4	3	3	1
90	187	2	3.7500	49.8705	14.1	40	40	40	1
91	187	3	6.2500	49.8705	14.1	20	19	19	1
92	187	4	8.7500	49.8705	14.1	21	21	21	1
93	187	5	11.2500	49.8705	14.1	4	4	4	1
94	188	4	8.7500	32.7026	17.1	1	0	.	1
95	188	5	11.2500	32.7026	17.1	2	1	1	1
96	188	6	13.7500	32.7026	17.1	3	1	1	1
97	188	7	15.2500	32.7026	17.1	5	2	2	1
98	188	8	18.5577	32.7026	17.1	13	5	5	1
99	188	9	21.2500	32.7026	17.1	12	7	7	1
100	188	10	23.7500	32.7026	17.1	18	7	7	1
101	188	11	26.2500	32.7026	17.1	3	0	.	1
102	188	12	28.7500	32.7026	17.1	3	0	.	1
103	188	14	33.7500	32.7026	17.1	1	1	1	1
104	190	1	1.2500	12.9104	14.0	1	1	1	1
105	190	2	3.7500	12.9104	14.0	2	2	2	1
106	190	3	6.2500	12.9104	14.0	1	1	1	1
107	190	4	8.7500	12.9104	14.0	3	3	3	1
108	190	5	11.2500	12.9104	14.0	2	2	2	1
109	191	1	1.2500	30.7544	19.0	1	0	.	1
110	191	2	3.4722	30.7544	19.0	9	0	.	1
111	191	3	6.2500	30.7544	19.0	3	1	1	1
112	191	4	8.7500	30.7544	19.0	3	2	2	1

APPENDIX V
PROGRAM TO SUMMARIZE INITIAL VSR CHARACTERISTICS

```
CMS FILEDEF FIXDATA1 DISK PSPSUM1 DATA;
 DATA PRACT;
  INFILE FIXDATA1;
    INPUT GRNUMB 1-4 PLNUMB 5 MEASNU 6 TRHAAL 7-11
          ARIDBHAL 12-16 .1 BASUMHA 17-24 .4 AVEHTAL
          25-29 .1 TRHA1 30-34 ARIDBH1 35-39 .1
          BASUMHA1 40-47 .1 AVEHT1 48-52 .1 SPCODEX 59;

  IF MEASNU > 0 THEN DELETE;
  PROC SORT; BY SPCODEX;
  RUN;


        /*  VSR3 */ ;

  DATA P1; SET PRACT;
    IF GRNUMB < 101 THEN DELETE;
    IF GRNUMB > 107 AND GRNUMB <111 THEN DELETE;
    IF GRNUMB > 128 AND GRNUMB <141 THEN DELETE;
    IF GRNUMB > 146 AND GRNUMB <151 THEN DELETE;
    IF GRNUMB > 154 AND GRNUMB <164 THEN DELETE;
    IF GRNUMB > 166 AND GRNUMB <557 THEN DELETE;
    IF GRNUMB > 557 AND GRNUMB <565 THEN DELETE;
    IF GRNUMB > 565 THEN DELETE;

   PROC MEANS DATA=P1 N MIN MAX MEAN STD;
     VAR TRHAAL ARIDBHAL BASUMHA AVEHTAL TRHA1
        ARIDBH1 BASUMHA1 AVEHT1;
      BY SPCODEX;


        /* VSR4 */;

   DATA P2; SET PRACT;
    IF GRNUMB > 43 AND GRNUMB < 181 THEN DELETE;
    IF GRNUMB > 214 AND GRNUMB < 226 THEN DELETE;
    IF GRNUMB > 258 AND GRNUMB < 352 THEN DELETE;
    IF GRNUMB > 359 AND GRNUMB < 365 THEN DELETE;
    IF GRNUMB > 366 AND GRNUMB < 388 THEN DELETE;
    IF GRNUMB > 399 AND GRNUMB < 423 THEN DELETE;
    IF GRNUMB > 425 AND GRNUMB < 457 THEN DELETE;
    IF GRNUMB > 459 AND GRNUMB < 545 THEN DELETE;
    IF GRNUMB > 546 AND GRNUMB < 584 THEN DELETE;
    IF GRNUMB > 585 AND GRNUMB < 599 THEN DELETE;
    IF GRNUMB > 610 AND GRNUMB < 615 THEN DELETE;
     IF GRNUMB > 615 AND GRNUMB < 901 THEN DELETE;
    IF GRNUMB > 924 AND GRNUMB < 930 THEN DELETE;
    IF GRNUMB > 938 THEN DELETE;

   PROC MEANS DATA=P2 N MIN MAX MEAN STD;
     VAR TRHAAL ARIDBHAL BASUMHA AVEHTAL TRHA1
        ARIDBH1 BASUMHA1 AVEHT1;
      BY SPCODEX;


       /*  VSR5 */ ;

 DATA P3; SET PRACT;
   IF GRNUMB < 55 THEN DELETE;
```

```
 IF GRNUMB > 90 AND GRNUMB < 361 THEN DELETE;
 IF GRNUMB > 361 AND GRNUMB < 462 THEN DELETE;
 IF GRNUMB > 464 AND GRNUMB < 602 THEN DELETE;
 IF GRNUMB > 602 THEN DELETE;

PROC MEANS DATA=P3 N MIN MAX MEAN STD;
  VAR TRHAAL ARIDBHAL BASUMHA AVEHTAL TRHA1
     ARIDBH1 BASUMHA1 AVEHT1;
   BY SPCODEX;


     /* VSR6 */;

DATA P4; SET PRACT;
 IF GRNUMB < 44 THEN DELETE;
 IF GRNUMB > 54 AND GRNUMB < 259 THEN DELETE;
 IF GRNUMB > 303 AND GRNUMB < 338 THEN DELETE;
 IF GRNUMB > 351 AND GRNUMB < 466 THEN DELETE;
 IF GRNUMB > 468 AND GRNUMB < 471 THEN DELETE;
 IF GRNUMB > 474 AND GRNUMB < 494 THEN DELETE;
 IF GRNUMB > 498 AND GRNUMB < 600 THEN DELETE;
 IF GRNUMB > 600 THEN DELETE;

PROC MEANS DATA=P4 N MIN MAX MEAN STD;
  VAR TRHAAL ARIDBHAL BASUMHA AVEHTAL TRHA1
     ARIDBH1 BASUMHA1 AVEHT1;
   BY SPCODEX;
RUN;
```

The SAS System
APPENDIX VI(A) VSR3

SW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	25	2696.60	1813.41	663.0000000	9210.00
ARIDBHAL	25	12.7160000	3.6173978	6.9000000	19.6000000
BASUMHA	25	36.8714960	10.1667452	17.0428000	53.8329000
AVEHTAL	25	14.4080000	1.9960210	10.5000000	17.7000000
TRHA1	25	1139.12	1226.82	25.0000000	4097.00
ARIDBH1	25	12.7600000	5.6841886	2.5000000	25.3000000
BASUMHA1	25	16.0694040	11.4695054	0.0126000	38.6714000
AVEHT1	24	14.4958333	2.9540656	8.2000000	20.0000000

PL

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	36	3414.19	2562.55	663.0000000	12723.00
ARIDBHAL	36	11.8888889	3.6849329	5.8000000	19.6000000
BASUMHA	36	35.5763222	10.5313443	2.8324000	53.8329000
AVEHTAL	36	13.0527778	2.8121660	5.8000000	17.7000000
TRHA1	36	2455.92	2688.92	25.0000000	12723.00
ARIDBH1	36	14.7777778	6.2461010	6.3000000	33.3000000
BASUMHA1	36	24.9950389	14.0217303	0.8430000	47.0368000
AVEHT1	35	13.6942857	3.1284222	6.8000000	19.5000000

AW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	9	1970.11	1277.08	718.0000000	4121.00
ARIDBHAL	9	13.5888889	4.7556399	5.8000000	19.6000000
BASUMHA	9	32.0967556	12.4818182	2.8324000	45.3864000
AVEHTAL	9	14.3444444	3.6421529	5.8000000	17.6000000
TRHA1	9	46.7777778	49.7035657	10.0000000	170.0000000
ARIDBH1	9	14.8888889	6.3977427	2.5000000	23.9000000
BASUMHA1	9	0.6938889	0.5708572	0.0913000	1.6067000
AVEHT1	7	13.5000000	4.1360206	4.8000000	17.4000000

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BW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	5	1631.20	1010.34	718.0000000	3210.00
ARIDBHAL	5	13.3800000	4.9901904	5.8000000	19.6000000
BASUMHA	5	28.4042400	16.1073553	2.8324000	46.7340000
AVEHTAL	5	13.4000000	4.5194026	5.8000000	17.3000000
TRHA1	5	53.6000000	55.8775447	10.0000000	148.0000000
ARIDBH1	5	12.3200000	6.3841209	1.2000000	17.5000000
BASUMHA1	5	1.1197400	1.5587649	0.0011000	3.8467000
AVEHT1	3	13.7333333	3.1754265	11.9000000	17.4000000

SB

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	17	2583.88	2163.95	718.0000000	9210.00
ARIDBHAL	17	12.9058824	4.2684117	5.8000000	19.6000000
BASUMHA	17	34.4791176	13.1274200	2.8324000	53.8329000
AVEHTAL	17	13.6588235	2.9351446	5.8000000	17.7000000
TRHA1	17	687.3529412	1363.86	10.0000000	4642.00
ARIDBH1	17	10.0000000	4.6392349	3.4000000	18.0000000
BASUMHA1	17	3.2128529	5.6149623	0.0858000	17.2881000
AVEHT1	13	9.2846154	3.3256193	3.0000000	13.4000000

FB

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	11	2292.91	1125.22	801.0000000	4173.00
ARIDBHAL	11	13.5272727	4.1792561	7.3000000	18.7000000
BASUMHA	11	37.8895818	9.7468840	17.0428000	53.8329000
AVEHTAL	11	14.4636364	2.3938558	10.5000000	17.7000000
TRHA1	11	599.1818182	1018.49	12.0000000	2818.00
ARIDBH1	11	11.4909091	5.4977185	2.9000000	19.8000000
BASUMHA1	11	6.1014909	9.2394481	0.0734000	29.9021000
AVEHT1	10	11.6700000	3.7490888	5.5000000	16.6000000

The SAS System

APPENDIX VI(B) V5R4

SW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	105	1387.07	1022.90	272.0000000	5704.00
ARIDBHAL	105	18.0095238	5.9604550	4.6000000	30.9000000
BASUMHA	105	33.4809448	13.9542813	6.4446000	83.8688000
AVEHTAL	105	18.7361905	4.6213577	6.6000000	26.5000000
TRHA1	105	316.5238095	467.5952111	4.0000000	2509.00
ARIDBH1	105	16.0704762	9.0059054	2.0000000	44.5000000
BASUMHA1	105	9.6852343	13.2807890	0.0032000	56.6457000
AVEHT1	78	16.5307692	7.8088246	1.9000000	27.7000000

PL

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	97	2102.69	1839.95	311.0000000	9505.00
ARIDBHAL	97	15.4680412	5.7015814	4.6000000	26.6000000
BASUMHA	97	33.1348804	13.4664022	1.4058000	63.0289000
AVEHTAL	97	16.9938144	4.4872694	5.1000000	26.4000000
TRHA1	97	1108.77	1062.46	5.0000000	6025.00
ARIDBH1	97	18.6216495	7.4752679	5.3000000	35.2000000
BASUMHA1	97	20.5824557	13.6892651	0.1493000	56.0663000
AVEHT1	90	17.5255556	4.4993523	5.1000000	26.9000000

AW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	77	1272.53	785.5252950	247.0000000	5000.00
ARIDBHAL	77	18.4584416	5.8865000	4.6000000	32.6000000
BASUMHA	77	34.6153455	14.2541351	6.4446000	83.8688000
AVEHTAL	77	19.4454545	4.3523903	6.9000000	26.5000000
TRHA1	77	324.3376623	502.9164839	10.0000000	3515.00
ARIDBH1	77	22.4285714	10.2064203	1.6000000	44.3000000
BASUMHA1	77	11.4715468	11.7725595	0.0046000	48.1644000
AVEHT1	55	19.4618182	6.1796108	2.2000000	27.5000000

The SAS System

BW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	71	1353.21	1167.18	247.0000000	7654.00
ARIDBHAL	71	18.8464789	5.9040623	4.6000000	32.6000000
BASUMHA	71	34.9161141	14.2480685	6.4819000	83.8688000
AVEHTAL	71	19.2943662	4.7806720	6.9000000	26.5000000
TRHA1	71	116.5774648	123.5171084	4.0000000	750.0000000
ARIDBH1	71	16.1183099	9.0756394	1.6000000	50.9000000
BASUMHA1	71	3.1776930	4.2764892	0.0044000	22.8166000
AVEHT1	39	16.4205128	8.0450436	2.5000000	31.1000000

SB

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	71	2760.35	1958.77	311.0000000	9505.00
ARIDBHAL	71	12.2619718	5.9065186	2.9000000	26.6000000
BASUMHA	71	30.1184127	15.4378860	2.3886000	63.0289000
AVEHTAL	71	13.4197183	6.0648783	2.9000000	26.4000000
TRHA1	71	1457.24	1911.15	10.0000000	7407.00
ARIDBH1	71	9.9366197	5.4743360	1.8000000	24.0000000
BASUMHA1	71	9.3993986	12.5643421	0.0127000	46.7438000
AVEHT1	54	10.5129630	4.6850644	2.4000000	19.6000000

FB

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	71	2154.35	1712.45	272.0000000	9900.00
ARIDBHAL	71	12.5591549	7.3782611	2.3000000	26.7000000
BASUMHA	71	26.3425944	18.6173136	0.8665000	83.8688000
AVEHTAL	71	12.6549296	7.6162006	2.5000000	25.1000000
TRHA1	71	1118.34	1646.26	5.0000000	9900.00
ARIDBH1	71	10.7788732	6.4575076	2.0000000	27.2000000
BASUMHA1	71	6.6882296	6.6301150	0.0031000	25.8944000
AVEHT1	54	10.1555556	6.6921150	2.5000000	24.2000000

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The SAS System

APPENDIX V1(C) VSR5

SW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	16	1234.69	1757.77	148.0000000	7358.00
ARIDBHAL	16	20.0312500	5.8349200	8.3000000	28.5000000
BASUMHA	16	27.7159312	11.5292595	11.5495000	48.6502000
AVEHTAL	16	18.4687500	3.6406444	11.6000000	25.2000000
TRHA1	16	201.7500000	287.2793066	5.0000000	949.0000000
ARIDBH1	16	20.1375000	12.6894641	1.8000000	52.8000000
BASUMHA1	16	6.9785687	8.9369890	0.0024000	28.7565000
AVEHT1	11	17.4272727	4.3437520	9.7000000	23.8000000

PL

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	34	2008.18	[illegible]549.6[illegible]	267.0000000	7358.00
ARIDBHAL	34	16.8470588	5.4381436	8.3000000	28.5000000
BASUMHA	34	34.8973912	7.1957395	16.7341000	51.8469000
AVEHTAL	34	17.5617647	3.5329629	11.2000000	25.2000000
TRHA1	34	1207.12	1048.45	10.0000000	4667.00
ARIDBH1	34	18.5970588	6.3945282	8.5000000	33.1000000
BASUMHA1	34	25.1694941	11.9619893	0.1021000	41.5468000
AVEHT1	34	18.1235294	3.9509921	9.5000000	27.0000000

AW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	16	1476.06	1029.62	267.0000000	3646.00
ARIDBHAL	16	17.3375000	4.3773470	10.1000000	23.3000000
BASUMHA	16	30.9308562	8.3894880	13.2599000	41.5524000
AVEHTAL	16	18.1125000	3.1279120	12.8000000	22.9000000
TRHA1	16	212.3750000	286.0552103	5.0000000	815.0000000
ARIDBH1	16	21.1312500	5.5553840	11.4000000	29.3000000
BASUMHA1	16	5.9049062	6.5187543	0.1258000	22.6280000
AVEHT1	12	19.5833333	3.3474097	14.7000000	24.8000000

The SAS System

BW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	13	1254.38	1884.44	148.0000000	7358.00
ARIDBHAL	13	19.5153846	5.0288909	8.3000000	26.8000000
BASUMHA	13	26.4245846	11.4054135	11.5495000	48.6502000
AVEHTAL	13	17.8461538	3.3723423	11.6000000	22.5000000
TRHA1	13	180.4615385	227.4395947	5.0000000	716.0000000
ARIDBH1	13	20.0230769	10.8084962	9.2000000	45.8000000
BASUMHA1	13	4.2944846	4.4946753	0.2507000	13.6045000
AVEHT1	10	14.6300000	5.7898474	4.6000000	21.9000000

SB

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	17	2599.24	2095.81	346.0000000	7358.00
ARIDBHAL	17	16.0294118	6.5211928	8.3000000	28.5000000
BASUMHA	17	36.5581353	8.0858408	23.8130000	51.8469000
AVEHTAL	17	17.0000000	4.2329068	11.2000000	25.2000000
TRHA1	17	1049.41	1480.43	5.0000000	5679.00
ARIDBH1	17	11.8235294	5.6306172	6.6000000	28.0000000
BASUMHA1	17	7.4286588	9.8694539	0.0461000	32.2713000
AVEHT1	13	13.5384615	4.1718378	9.5000000	22.6000000

FB

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	5	1025.80	981.4564178	148.0000000	2668.00
ARIDBHAL	5	19.9400000	5.6176508	11.6000000	26.8000000
BASUMHA	5	28.4630000	11.7519978	11.5495000	39.6586000
AVEHTAL	5	19.1400000	2.1066561	16.0000000	21.3000000
TRHA1	5	478.4000000	724.7856925	20.0000000	1700.00
ARIDBH1	5	15.8200000	6.7458876	7.7000000	25.4000000
BASUMHA1	5	4.6320400	4.8202136	0.2802000	10.0324000
AVEHT1	4	15.3750000	2.2911060	12.8000000	18.3000000

The SAS System
APPENDIX VI(D) VSRG

SW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	77	1227.79	756.5883665	277.0000000	6049.00
ARIDBHAL	77	19.7818182	6.1681424	5.3000000	35.9000000
BASUMHA	77	39.4552558	8.8987577	18.8824000	57.6323000
AVEHTAL	76	21.4578947	3.1931703	14.6000000	27.1000000
TRHA1	77	627.4415584	625.2290632	5.0000000	4790.00
ARIDBH1	77	20.9038961	7.7732240	4.5000000	51.3000000
BASUMHA1	77	20.5615481	10.7661482	0.0314000	44.6192000
AVEHT1	69	21.7130435	3.6147538	12.5000000	29.5000000

PL

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	37	1259.54	576.5626397	277.0000000	2617.00
ARIDBHAL	37	20.0054054	6.0656568	6.7000000	35.9000000
BASUMHA	37	40.7549541	7.6835389	25.4753000	56.2251000
AVEHTAL	37	22.0351351	2.9268125	17.3000000	27.1000000
TRHA1	37	267.4594595	323.5742740	10.0000000	1273.00
ARIDBH1	37	26.6000000	5.7424830	15.7000000	37.7000000
BASUMHA1	37	11.1896973	9.6367084	0.4322000	35.8226000
AVEHT1	21	22.1809524	3.5086492	16.9000000	30.2000000

AW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	70	1198.69	754.1951568	277.0000000	6049.00
ARIDBHAL	70	19.8871429	6.2564731	5.3000000	35.9000000
BASUMHA	70	38.3672743	9.1912598	18.8824000	57.6323000
AVEHTAL	69	21.2913043	3.2018717	14.6000000	27.1000000
TRHA1	70	322.1714286	332.4961358	10.0000000	1512.00
ARIDBH1	70	24.6928571	8.8786068	7.9000000	44.8000000
BASUMHA1	70	11.6619071	7.9672235	0.6617000	35.0657000
AVEHT1	33	20.2484848	5.0660094	6.6000000	28.8000000

The SAS System

BW

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	67	1236.00	798.3783944	277.0000000	6049.00
ARIDBHAL	67	19.5597015	6.5337367	5.3000000	35.9000000
BASUMHA	67	37.9235493	8.5941390	18.8824000	57.6323000
AVEHTAL	66	21.1560606	3.2976975	14.6000000	27.1000000
TRHA1	67	130.9552239	177.4402531	5.0000000	870.0000000
ARIDBH1	67	19.5895522	9.7496874	2.0000000	48.5000000
BASUMHA1	67	3.9202985	4.9344540	0.0031000	24.0241000
AVEHT1	18	15.6555556	7.8058215	2.8000000	26.5000000

SB

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	12	1277.25	667.7736586	598.0000000	2617.00
ARIDBHAL	12	20.4250000	4.9909236	9.5000000	27.4000000
BASUMHA	12	41.9734750	7.2912992	28.7722000	52.4848000
AVEHTAL	12	20.9833333	2.5135391	17.3000000	25.4000000
TRHA1	12	161.5000000	213.3471350	10.0000000	672.0000000
ARIDBH1	12	17.9666667	4.3936593	7.9000000	24.9000000
BASUMHA1	12	4.5748667	6.4045432	0.1913000	21.1173000
AVEHT1	3	17.6666667	3.6143234	15.1000000	21.8000000

FB

Variable	N	Mean	Std Dev	Minimum	Maximum
TRHAAL	23	1268.70	614.7718302	381.0000000	2617.00
ARIDBHAL	23	19.8608696	6.5682251	6.7000000	33.8000000
BASUMHA	23	43.2121522	7.2636712	25.4753000	54.9336000
AVEHTAL	23	22.9913043	2.5421739	17.8000000	27.1000000
TRHA1	23	466.2608696	619.2207873	5.0000000	2077.00
ARIDBH1	23	13.3782609	8.0162311	4.1000000	32.0000000
BASUMHA1	23	4.1146087	4.9250081	0.0224000	21.9061000
AVEHT1	7	15.9142857	4.4551201	8.8000000	22.0000000